AL/HR-TR-1995-0005

ARMSTRONG LABORATORY

THE ENHANCED CONTINGENCY LOGISTICS PLANNING AND SUPPORT ENVIRONMENT (ECLIPSE): THE VISION

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January 1995

Final Technical Report for the Period September 1993 to September 1994

AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-7604

NOTICES

This report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1995	Final - Sep 93 to Sep 94

4. TITLE AND SUBTITLE
The Enhanced Contingency Logistics Planning and Support Environment (ECLiPSE): The Vision

5. FUNDING NUMBERS
C - F33657-92-D-2055
PE - 62205F
PR - 1710
TA - 00
WU - 54

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Human Resources Directorate
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2698 G Street
Wright-Patterson AFB, OH 45433-7604

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
AL/HR-TR-1995-0005

11. SUPPLEMENTARY NOTES
Armstrong Laboratory Technical Monitor: Capt William Z. Zeck, AL/HRGO, DSN 785-2606

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This report documents the first technical effort associated with the Armstrong Laboratory, Logistics Research Division's (AL/HRG) Enhanced Contingency Logistics Planning and Support Environment (ECLiPSE) research and development (R&D) initiative. The goal of this initiative is to demonstrate how advanced technologies can improve the quality and timeliness of wing logistics planning and replanning for short-notice contingency operations. This effort developed preliminary concept specifications for the operational components and relevant information technologies for a notional "ECLiPSE system". This report documents the study of the logistics planning process in order to identify how state-of-the-art software technologies can improve wing logistics planning in short-notice crisis situations. More specifically, the report documents the analysis of the Air Force (AF) wing logistics planning/replanning process and the software tools that support it to conceptualize the ECLiPSE vision. An ECLiPSE vision was formulated to guide laboratory investment aimed at improving AF wings' capabilities to plan and replan for short-notice tasking. This report describes: (1) the current and planned wing logistics planning environment, (2) the components comprised by the preliminary ECLiPSE vision, and (3) the current state of the relevant technologies as they apply to the ECLiPSE system.

14. SUBJECT TERMS
Deployment
Mobility
Logistics
Planning

15. NUMBER OF PAGES
76

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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PREFACE

This report documents the first technical effort associated with the Armstrong Laboratory, Logistics Research Division's (AL/HRG) Enhanced Contingency Logistics Planning and Support Environment (ECLiPSE) research and development (R&D) initiative. The goal of this initiative is to demonstrate how advanced technologies can improve the quality and timeliness of wing logistics planning and replanning for short-notice contingency operations. The goal of this effort was to develop preliminary concept specifications for the operational components and relevant information technologies for a notional "ECLiPSE system."

AL/HRG intends to use the results of this effort as a starting point for future investigations and demonstrations in this area. The ECLiPSE vision documented in this report is not final; as users get more involved in defining ECLiPSE, the specifications will evolve based on their feedback. This report serves three functions: (1) document the effort, (2) guide AL/HRG and other Department of Defense investment in research in this important area, and (3) communicate the preliminary ECLiPSE vision to AL/HRG's Air Force (AF) customers.

Throughout the study, the authors depended on the cooperation of many Air Force personnel. Numerous logisticians and maintainers from the 366th Wing, 52nd Wing, 36th Fighter Wing, and the 906th Fighter Group gave their time to explain the intricacies and problems associated with AF logistics planning processes. Various headquarters and agency personnel were also vital to the effort. LtCol Burleson, Capt Leftwich, and Mr. Newhouse from Air Staff; LtCol Butz and Capt Jennings from the Air Force Logistics Management Agency (AFLMA); Maj Moore from AF Special Operations Command (AFSOC); Capt Gage, Capt Miyares, MSgt Steffee, and TSgt Sherman from Air Combat Command (ACC); and Maj Edwards, Capt Talley, and Mr. Demaree from the Standard Systems Center (SSC) contributed by providing information on upgrades to current systems and new systems under development, by verifying our conclusions, and by providing feedback on our initial attempts to define the ECLiPSE vision.

The authors also extend their thanks to AL/HRG management and personnel for their support and patience throughout the study effort. Mr. Cream, Mr. Johnson, and LtCol Smoot reviewed the results of the study on more than one occasion -- each time providing critical insight. Capt Gwartney provided numerous "sanity checks" throughout the effort. 1Lt Carrico helped the authors synthesize and integrate information on the relevant technologies. Together, the contributions from AL/HRG personnel were essential to the successful completion of this important R&D effort.

THE ENHANCED CONTINGENCY LOGISTICS PLANNING AND SUPPORT ENVIRONMENT: THE VISION

SUMMARY

This report documents the results of Task #33 of the Supportability Investment Decision Analysis Center (SIDAC) contract. The effort, entitled "Enhanced Contingency Logistics Planning Support Environment (ECLiPSE)," was sponsored by the United States Air Force (USAF) Armstrong Laboratory, Logistics Research Division, Wright-Patterson AFB, Ohio. The Analytic Sciences Corporation (TASC) located in Fairborn, Ohio, performed the majority of the work.

The primary goal of Task #33 was to study the logistics planning process in order to identify how state-of-the-art software technologies can improve wing logistics planning in short-notice crisis situations. More specifically, the study team examined the Air Force (AF) wing logistics planning/replanning process and the software tools that support it to conceptualize the ECLiPSE vision. The vision was formulated to guide laboratory investment aimed at improving AF wings' capabilities to plan and replan for short-notice taskings. This report describes: (1) the current and planned wing logistics planning environment, (2) the components comprised by the preliminary ECLiPSE vision, and (3) the current state of the relevant technologies as they apply to the ECLiPSE system.

INTRODUCTION

Today's wing logistics planners rely on many sources of information and a myriad of supporting computer systems to help determine the resources and manpower to deploy in crisis situations. Reviews of the utility of these information sources and the effectiveness of currently used software systems conducted in the aftermath of Desert Shield/Storm identified numerous problems.[1] To a large degree, the AF is addressing these problems by fielding a suite of new, integrated software systems.[2] Unfortunately, these programs will not solve all the current problems and, more importantly to this research and development (R&D) initiative, do not address some of the fundamental shortcomings of the current planning process. The ECLiPSE vision was formulated to guide laboratory

[1] The most beneficial sources used to make these conclusions were: (1) the USAF Joint Unit Lessons Learned database (particularly logistics plans lessons learned), (2) Air Force Logistics Management Agency reports, and most importantly (3) the study team's interviews with wing and headquarters level personnel.

[2] The AF is upgrading many logistics planning systems and integrating them under an initiative called the Integrated Deployment System (IDS). One component of IDS is a new system, being developed by the Air Force Logistics Management Agency (AFLMA), called the Automated Mobility Planning System (AMPS). The AF is also creating the foundation for a standard, integrated wing information system through the Wing Command and Control System (WCCS) program. Each of these initiatives is discussed in more detail in Section IV.

research aimed at addressing the fundamental shortcomings that result from technology limitations.

The current ECLiPSE vision assumes that future wings will have a network infrastructure and an operating environment based on the Open System Environment (OSE) standard. These assumptions are consistent with the direction being taken by the industry and with AF plans to develop new systems and upgrade current wing logistics planning systems (Standard Systems Center, 1994b). These assumptions will allow components of ECLiPSE to be developed as separate modules with limited interfaces to existing and planned systems. The current ECLiPSE vision is an integration of three projects. Each project concept was driven by the desire of AF planners for a more accurate, timely, and flexible wing logistics planning capability.[3]

The first ECLiPSE project is the Deployment Information and Support Environment (DISE). DISE is composed of two parts. The first is a centrally located information system called the Deployment Knowledge Base (DKB). The DKB will provide fast access to in-depth audio, visual, and textual information pertaining to potential deployment sites (for readers familiar with the current airfield information system, think of the DKB as the next generation airfield information source). The types of information stored in the DKB include site specific maps, site- and region-specific lessons learned, airbase infrastructure information, and information on local suppliers of off-the-shelf resources. The goal of the DKB portion of ECLiPSE is to provide all wing planners with immediate access to near real-time information about the specific sites to which their units might possibly be deployed. The second part of DISE is the DKB's input and user interface mechanisms. An automatic lessons-learned recording system (ALLRS) and a multimedia airbase information collection tool (Multimedia Air Field Information System (MAFIS)) constitute the primary input mechanisms for the DKB. Conceptually, the DKB will be distributed and available to every Air Force unit through satellite links and wide area networks. Users will have the capability to query and edit the DKB from both remote and home stations.

The second ECLiPSE project is the Unit Type Code Development, Tailoring, and Optimization (UTC-DTO) tool. UTC-DTO is composed of two subcomponents: (1) an automatic UTC development and tailoring capability and (2) an automatic palletization optimization system. The development and tailoring part of this component will automatically generate or tailor UTCs for a specific mission. During a crisis, this component will automatically highlight all the items in the tasked UTC that need to be tailored into or out of the package. UTC-DTO will use information stored in the DKB, along with other important pieces of information, as inputs to the automatic tailoring process. The optimization part of this component will automatically generate near-optimal pallet arrangements based on the tailored UTCs.

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[3]The "desires of planners" were determined through an extensive literature search that focused on AF logistics planning problems and numerous interviews with both operational and headquarters personnel. The literature search and the interview methodology and results are described in Section III and Section IV, respectively.

The third ECLiPSE project is the Logistics Analysis to Improve Deployability (LOG-AID). LOG-AID will rigorously analyze the mobility and deployment process at the wing and unit level from receipt of a Time Phased Force Deployment Listing (TPFDL) until the associated cargo and personnel are packed, prepared, and ready to board a conveyance to the mission area. It also recommends innovative processes and technologies to improve the current process.

Each component will leverage state-of-the-art information technologies such as distributed computer-based audio and visual communications, artificial intelligence (AI) and decision support techniques, multimedia, distributed data management, advanced simulation techniques, and object-oriented design methodologies. For example, AI techniques will be very useful in the development of UTC-DTO. Distributed multi-media data management will be very useful in the development of the DKB. Together, these technologies can significantly enhance wing logistics planning in crisis situations.

The three integrated projects of the ECLiPSE vision will lead to a broader program called Total ECLiPSE. Total ECLiPSE will bring together everything learned from ECLiPSE and its three projects (DISE, LOG-AID, and UTC-DTO) into a total deployment concept for future deployments. The goal of Total ECLiPSE is to use a fighter wing as the test base for a totally re-engineered deployment process.

METHODOLOGY

In formulating the ECLiPSE vision, the study team (made up of AL/HRG and TASC personnel) focused on: (1) wing and unit logistics planning, (2) crisis planning and replanning (as opposed to deliberate planning), and (3) long-range technology solutions to logistics planning problems. The primary reason the study team focused on wing logistics planning as opposed to other "levels" of planning is that AF and Department of Defense (DoD) research organizations are already highly involved in developing and demonstrating information technologies for theater command and Joint Task Force (JTF) level logistics planning.

In formulating the ECLiPSE vision, AL/HRG and TASC researchers first carried out an extensive literature review that focused on identifying wing logistics planning problem areas. In general, the literature review highlighted contingency planning problems related to the reliability and level of integration of current planning systems, the accuracy and availability of needed information, and the amount of time necessary to accurately plan and replan for short-notice taskings.

In addition to reviewing documents, the study team discussed deployment planning problems with personnel from numerous operational AF units, headquarters organizations, and the AF Logistics Management Agency (AFLMA). The purpose of these discussions was to verify and clarify the problem areas highlighted during the literature search. The organizations that were contacted for this purpose are:

- 366th Wing (Mt. AFB),
- 52nd Wing (Spangdahlem AFB),
- 36th Fighter Wing (Bitburg AFB),
- 906th Fighter Group (Wright-Patterson AFB),
- HQ ACC/LGX,
- HQ AFSOC/LGX,
- HQ USAF/LGX, and
- AFLMA/LGX.

The study team also collected information on initiatives that are addressing many of the problems experienced during Desert Shield/Storm. The literature review conducted to investigate logistics planning problems was very useful for this task because it revealed numerous systems currently in use or under development. Armed with knowledge of these systems, the study team interviewed developers, users, and maintainers of these systems in order to gain a greater appreciation for the systems' current utility and, more importantly, the systems' future in AF wing logistics planning. The systems investigated in this manner are:

- Integrated Deployment System (IDS),
- Wing Command & Control System (WCCS),
- Contingency Operation Mobility Planning & Execution System (COMPES),
- Combat Readiness & Infrastructure Support Information System (CRISIS),
- Automated Mobility Planning System (AMPS),
- Computer-Aided Load Manifesting (CALM) System, and
- Cargo Movement & Operation System (CMOS).

Based on the problems found in wing-level logistics planning, the study team set out to develop the ECLiPSE vision. The team first reviewed literature to determine the current state of the art for a wide variety of information technologies, including distributed computer-based audio and visual communications, AI and decision support techniques, multimedia distributed data management, advanced simulation techniques, and object-oriented design methodologies. The ECLiPSE vision was then developed through a series of brainstorming sessions with technologists and representatives from SSC, AFLMA, Air Staff, ACC, and AFSOC.[4]

[4]Air Mobility Command (AMC) did not participate in any of the brainstorming sessions. This was the result of time/budget constraints and the authors' focus on combat unit deployment planning and replanning. (At the time this report was being drafted, AL/HRG was in the process of establishing a dialogue with HQ AMC/LGX.)

DATA ANALYSIS

After talking to many logisticians and reviewing regulations, specifications on new and existing systems, journal articles, and lessons learned reports (from Desert Shield/Storm), the study team developed an understanding of the current wing planning environment. The following sections briefly explain the current wing-level deployment planning environment and discuss several problem areas that are the impetus for ECLiPSE research.

Current Wing Logistics Planning Environment

As previously stated, the study team focused on the **wing** logistics planning/replanning process for **short-notice, crisis** situations. This section introduces the wing deployment planning and replanning process by (1) introducing the types of information used, (2) discussing the computerized information systems that support the process, and (3) summarizing the general problems that were identified during the study. The aim is not to provide a detailed or complete description of the process; other documents do this (e.g., AFR 28-3, AFR 28-4, AFR 28-6, etc.). Instead, the aim is to explain the study team's view of the wing logistics planning process. This section is important because it describes the "view" used to formulate the ECLiPSE vision.

Logistics Planning Information

Wing personnel require a wide variety of information in order to quickly and accurately plan and replan for short-notice taskings. Five important types of information are (1) expected length and pace of operations, (2) other units that are deploying to the same location, (3) beddown location attributes, (4) maximum manpower and material that can be deployed, and (5) type and amount of airlift allocated to the unit. Each type of information is discussed below.

Expected length and pace of operations

The manpower and materiel required to support a unit's part of the Operational Plan(OPLAN) may be significantly affected by the length of the deployment and the pace of the deployment operations. Most subjects interviewed assumed that higher sortie generation rates would require more materiel and personnel. Typically, longer sortie durations were also assumed to increase materiel requirements, but actual Desert Shield/Storm data contradicts that assumption. Discussions with HQ USAF/LGS indicated that many projections of spares usage were three to four times greater than actual requirements. While this outcome was viewed as being better than having insufficient in-theater spares, clearly there is potential for more effective use of airlift. Obviously, if aircraft are not hauling unneeded spares, they can be tasked to haul additional combat capability.

The model used for equipment projections was the Dynametric model, which is also used for the equipment capability portion of the Status of Resources and Training

System (SORTS) reports (AFR 55-15). According to HQ ACC/LGS, the Dynametric model tends to project a linear increase in required numbers of spare parts with increasing sortie duration. In practice, this is typically a poor assumption because many failures (especially avionics failures) are associated more with power cycling or ground operations rather than with a longer cycle. Algorithms for the Dynametric model were already being analyzed for modification during this study, and a more realistic projection capability will probably exist in the Dynametric version that will be available by the time this report is published.

In addition to the spares-projection errors caused by the assumption that longer sortie durations equate to higher spares usage, Dynametric may project incorrect quantities based on failure rate data input to the model. According to HQ USAF/LGS, fleet-wide data is used for failure rates. When significant quantities of aircraft exist at locations approximating the climate and conditions of the deployment location, it would be beneficial to take the appropriate "slice" of the fleet-wide failure rate data to obtain specific failure projections for the area of interest. Another potential reason for the number of bad projections on spares requirements is the use of standard planning factors from the War Mobilization Plan, Volume 5 (WMP-5) for sortie length and duration for different aircraft types. The implication is that these factors are based on a European scenario that does not correspond entirely with the situation in the Gulf, according to HQ USAF/LGS and HQ ACC/LGS.

Units Deploying to the Same Operating Location

Associated with each OPLAN for anticipated force employment is a Time-Phased Force Deployment Document (TPFDD) file. Its contents are typically seen at the unit level in the form of a list, the TPFDL, which contains information on (1) in-place units; (2) units to be deployed and their order of deployment and port of debarkation; (3) routing of forces being deployed; (4) non-unit-related cargo and personnel movements; and (5) transportation requirements for common-user lift and organization-owned transportation resources. The TPFDL provides a list of all units deployed to different geographic locations (GEOLOCs) within the OPLAN, and the Unit Type Codes (UTCs) expected to be deployed (Patrick et al, 1989). By knowing which other units will be at the same location, a unit can coordinate to share common resources and avoid airlifting redundant equipment. Time-phasing units provides wing planners with dates that must be met to successfully implement the deployment portion of the OPLAN. These dates form the basis for the entire deployment process.

Beddown Location Attributes

Several different sources are typically accessed to obtain information on the deployed location. These include the Automated Air Field Information File (AAFIF), reports from advanced deployment teams, and detailed site surveys. This information can be used by the deploying unit to help tailor UTCs to meet specific needs at specific locations. If local sources can be obtained for fuel, transportation, aircraft loading, and so forth, significant reduction in airlift is possible. Other factors might significantly change

the order in which elements are shipped. For example, reports of terrorist activity might result in a decision to transport additional security police in the initial phase of the deployment. Reported conditions of runways, parking areas, hangars, dormitories, and the like, could affect the tailoring of UTCs as well.

Maximum Manpower and Material that can be Deployed

The basic Air Force document controlling deployment is the UTC. Everything that is initially deployed with a unit is listed in the UTC. UTCs are listed in the TPFDD as five-character identifiers that uniquely specify a force or support package. Along with the UTC, a completed TPFDD lists a specific unit, the Unit Identification Code (UIC), tasked to fill the UTC requirement. The majority of the UTC consists of the manpower/logistics detail, contained in the manpower force element listing (MFEL) and the logistics detail (LOGDET). The MFEL is broken down by Air Force Specialty Code (AFSC) type and quantity of personnel, and a code specifying where each person will be working. The LOGDET specifies a list of all the equipment needed, including weight, size, shipping characteristics, national stock numbers, and the increment number for each item. The increment number specifies the order in which the equipment is transported; typically, each increment is a pallet of material or a piece of wheeled equipment (Aerospace Ground Equipment, vehicle, etc.) (Patrick, 1989).

Standard UTCs are developed by "pilot" units as benchmarks for other units. A pilot unit is a unit tasked to develop a standard UTC for use by all units equipped with a specific weapon system. The pilot unit acts as a single point of contact for development and maintenance of a standard UTC. Pilot units report the LOGDET data to the Major Command (MAJCOM) for inclusion or update of the MAJCOM logistics force packaging subsystem called LOGFOR. When a unit is tasked to deploy a UTC, it may deploy the standard UTC or a tailored UTC. The process of tailoring the UTC from the standard UTC is done at the unit level and involves consideration of specific deployment conditions. Creation of the standard UTCs, as well as tailored UTCs, is a labor-intensive process, with little help from automated tools. At the 366th Wing at Mountain Home AFB, construction of the standard force packages for a combined wing structure was accomplished by manually listing the required equipment and personnel on white boards on all walls of a large conference room. Tailored UTCs are based on assumptions of where they will be deployed, which is given in the OPLAN. Short-notice deployments in the future may necessitate much faster tailoring UTCs, using the one that most closely fits the anticipated situation.

Type of Airlift Allocated

Each unit needs to load plan its UTCs based on the type of aircraft it will be using for transport. Load planning involves deciding how equipment will be palletized and how the pallets will be loaded on the particular aircraft while maintaining aircraft center-of-gravity requirements.

Supporting Systems

In addition to focusing on the types of logistics planning information, the study team analyzed current and future logistics planning systems and tools. There are many systems being used, current systems being upgraded, and new systems being developed. The study team focused on this area for three reasons: (1) to identify problems associated with the current systems, (2) to understand what problems the new and upgraded systems were addressing, and (3) to ensure that the ECLiPSE Vision is compatible with the AF's planned wing-level operating environment.

The primary AF logistics planning system COMPES, governed by AFR 28-6. COMPES has base- and MAJCOM-level components. It also interfaces with the Joint Operation Planning and Execution System (JOPES). Although COMPES' components and interfaces are complex, the base-level portion of the system, comprised of LOGMOD-B and MANPER-B, is relatively simple to understand. LOGMOD-B's primary function is to allow units to retrieve, store, and edit the equipment associated with UTCs. It answers the critical question, "What do we take on this deployment?" MANPER-B provides a similar capability for planning personnel deployments. It answers the question, "What type and how many people need to deploy?"

Although COMPES is the official AF wing logistics planning system, wings also rely on many other systems for planning and executing deployments. These systems, along with a suite of new/upgraded systems, are being integrated under an initiative called the Integrated Deployment System (IDS). Additional new systems like the Global Command and Control System (GCCS which is replacing the World-Wide Military Command and Control System (WWMCCS)), the WCCS, and CRISIS will play important roles in the future wing logistics planning process.

An important feature common to all upgraded and new systems, is that they are being developed using the "open systems" approach. Thus, the new/upgraded applications will be more flexible, portable across different platforms, and capable of operating on networks comprised of varied computer hardware and software applications.[5] **This is relevant because the future wing computing environment (being defined by these ongoing programs) will allow ECLiPSE components to seamlessly interface in the same environment.**

The paragraphs below briefly introduce the systems that will define the environment in which ECLiPSE will operate. The aim is twofold: (1) to introduce the uninitiated reader to these systems and provide references for more detailed information, and (2) to discuss the systems' importance to the ECLiPSE Vision. Current and upgraded

[5]The term "open systems" refers to a federal government standards initiative and the general industry software development trend. In current practice, the "open systems approach" means: (1) the Unix operating system, (2) X Windows, (3) Structured Query Language (SQL), the Initial Graphics Exchange Specification (IGES), the Graphical Kernel System (GKS), and other software development standards.

systems are discussed as components of IDS. WCCS and CRISIS are discussed as separate systems.

Integrated Deployment System (IDS)

IDS is the integration of several base-level automated systems, some of which are upgraded systems and some of which are new. These include the LOGMOD-B Modernization, AMPS, MANPER-B, CMOS, and CALM.

COMPES and LOGMOD-B. Although contingency planning has been done at the unit level in some fashion since the formation of the armed forces, the process has only been formalized to a large degree for the United States Air Force (USAF) since the late 1970s, with the institutionalization of COMPES. COMPES grew out of the discovery of problems with deployments to Southeast Asia in 1972 through 1973. Some of these problems were due to the inability of various command-unique mobility systems to talk to one another, except through manual data translation (Department of the Air Force, 1985).

The development of a standardized system was chartered in 1975; AFR 28-6 (March 1985) describes the top-level use of the resultant COMPES system. COMPES provides a means of communicating OPLANs from the Joint Chiefs of Staff (JCS) level to AF units, allows those units to provide detail for materiel and personnel necessary to fulfill the OPLANs, permits revision to OPLANs and unit requirements, and coordinates airlift and shipping assets. Existing computer hardware and networking capabilities at the time of the development of COMPES limited the degree to which the original vision for the system could be achieved practically. New hardware capabilities have allowed these limitations to be addressed, as discussed in the following section.

Figure 1 shows the basic structure of COMPES and the information flow across the chain of command. The major modules of COMPES are LOGMOD, MANPER, and OPSMOD. LOGMOD provides for the planning of materiel shipment based on the standard UTCs, answering the important question, "What do we take on this deployment, and in what order do we ship it?" MANPER provides a similar capability for planning personnel deployments, "Who do we need to send, and who goes first?" LOGMOD and MANPER each have a base (suffix "-B") and major command (suffix "-M") component, which are required to communicate information to each other as plans or readiness levels change. This communication has historically been inadequate due to low-bandwidth, low-reliability communications channels. OPSMOD integrates inputs from LOGMOD-M and MANPER-M (the MAJCOM components) for consolidated input to the JOPES, and also provides information from JOPES for those modules.

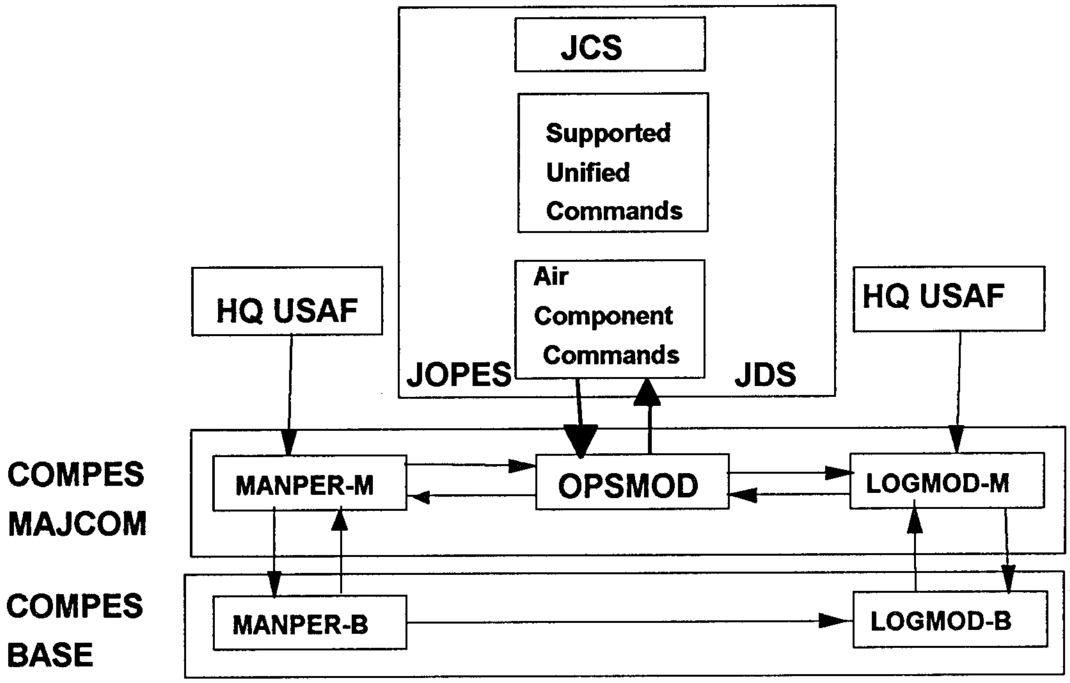

Figure 1
COMPES and Its Interfaces

This study focused on planning processes at the unit level. LOGMOD-B and MANPER-B are the formal tools used, but there is a lot of informal planning done before equipment and personnel lists get input into these systems. The units spend considerable time manually marking up LOGMOD-B and MANPER-B printouts, entering them into informal computer analysis tools, and eventually re-entering the data into the base COMPES modules. The base-level interviews indicate that much time is currently wasted during planning and execution deployment phases as a result of re-entering data in different formats, and that integration of the existing systems either by standardization of file formats or development of conversion routines would improve the situation significantly.

These problems have been recognized for some time, and the Air Force Logistics Management Center (AFLMC) and the SSC have taken leading roles in addressing and correcting the deficiencies. A variety of new generation, integrated tools are currently in development, and some are well into the field-test stage.

In general, the new tools are targeting an "open systems" development approach. The term "open systems" refers to the federal government's initiative to develop an overall computing environment based on open, consensus-based standards, which will encompass "the functionality needed to provide interoperability, portability, and scalability of computerized applications across networks of heterogeneous, multivendor hardware/software/communications platforms." (National Institute of Standards and Technology Special Publication 500-210, 1993). In current practice, this is interpreted to mean Unix workstations, X Windows user interfaces, Initial Graphics Exchange Specification (IGES), Programmer's Hierarchical Interactive Graphics System (PHIGS), Graphical Kernel System (GKS), and Computer Graphics Metafile (CGM) graphics standards, and data manipulation (Structured Query Language) and transport (Government Open System Interconnection Profile) standards.

Some tools being considered are a new version of LOGMOD-B, WCCS, CMOS, and AMPS. There is also a new version of MANPER-B hosted on a personal computer. Each of these systems will enable significant improvements in various parts of the contingency planning and operations process.

Upgraded LOGMOD-B. If implemented, the new version of LOGMOD-B will be hosted on Sun and Hewlett-Packard (HP) workstations, using the Unix operating system and the Motif X-window user interface. Each wing Logistics Plans office will have a workstation with five X-terminals, laser and high speed printers. The local machine will be tied by a high-speed network link to one of eight Regional Processing Centers (RPCs), which will act as centralized database servers. These centralized RPCs will give MAJCOMs full visibility of the deployment data from their respective bases (SSC, November 1994a).

The majority of the functionality in the revised LOGMOD-B system is essentially re-implemented from the original mainframe version. The big difference in these existing functions will be the access speed to desired data across the high-speed network connections. LOGMOD-B is primarily used to create standard UTCs and tailor existing UTCs for specific OPLANs. The new system will allow much easier editing of data with the new graphical user interface and will provide portability of data formats across the Standard Base Supply System (SBSS), CALM, CMOS, MANPER-B, and WCCS for mutually required data.

New functionality in the workstation version of LOGMOD-B includes the capability to view TPFDD data and query the SBSS to determine availability of required UTC items.

CALM. CALM is a personal computer (PC) -based software program that allows users to load plan different transport aircraft, including the C-130, C-141, C-5, and KC-10. It provides a graphical display of pallet locations on the different aircraft, allows users to move pallets to different locations, automatically calculates center of gravity restrictions, and reads data directly from electronic CMOS inputs. CALM's output tells aircraft loaders how to position the cargo on the flightline for loading onto the specified

aircraft. The latest version of CALM demonstrated to the study team did not have support for Civil Reserve Air Fleet (CRAF) aircraft (747, DC-8, etc.), which was one weakness identified during the Desert Shield/Storm operations (Hagel et al, 1992). CALM was apparently not widely used during the Gulf conflict. The Strategic Air Command (SAC) bases involved in the deployment used mostly organic airlift, and the "stuff it in until it is full" method of load planning was apparently common (Hagel et al, 1992).

Cargo Movement and Operations System(CMOS). CMOS is a software application that facilitates inventory control on cargo being airlifted or shipped. It generates MILSTAMP-required shipping documentation to be attached to pallets and provides for tracking of shipments in transit. It also provides cargo status to the C2 elements and passes detailed cargo records via diskette to the load planning program (currently CALM). CMOS will provide for hazardous material processing and identify potential shipment consolidations and packaging requirements. In its final form, it will allow input using hand-held terminals (similar to units used by overnight package delivery services), manual keyboard input, and radio frequency (RF) scanner transmissions (SSC, 1994).

Automated Mobility Processing System (AMPS). AMPS is a PC-based windows application that allows the squadron-level mobility planner to create and modify equipment and personnel lists that are electronically format compatible with the base-level COMPES (Jennings, 1994). It also provides the capability to convert these files into a form useable by CMOS and to generate travel orders automatically from the personnel listings. Prior to AMPS, the unit-level planner spent considerable time marking up printed listings and re-entering them into other automated systems. AMPS allows "electronic mark-ups" to be made and fed directly into other systems like LOGMOD-B, MANPER-B, CMOS, and CALM. AMPS also provides for personnel immunization management. Figure 2 shows the large number of system interfaces that AMPS has automated.

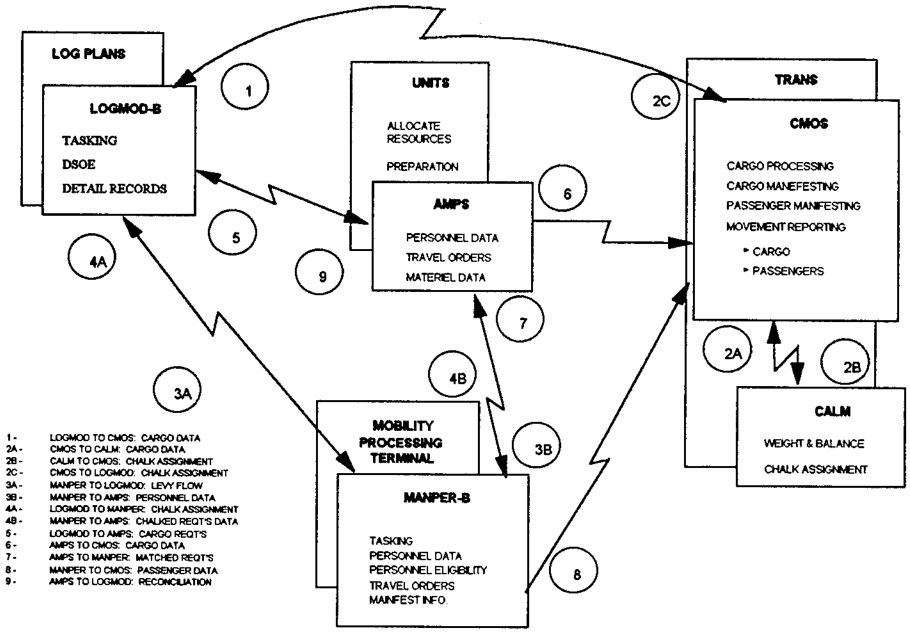

Figure 2
Automated Mobility Processing System (AMPS) and Interfaces with Other Tools

Wing Command and Control System

AF WCCS is a new information system currently under development by the WCCS System Program Office (SPO) at Gunter AFB. The primary goal of WCCS is to enhance the wing battle staff's access to critical information from the functional areas on an airbase. A secondary benefit will be the resulting improvement in communication between functional groups.

WCCS is currently hosted on Sun workstations. It uses a Motif graphical user interface to give WCCS users rapid navigation capabilities of the information database. The database is implemented using ORACLE Version 7, which provides client-server functionality across the WCCS network. WCCS is a distributed system, with workstation nodes connected via high speed communications lines. Figure 3 shows a notional sketch of the WCCS architecture, including nodes for some of the major base information providers and requesters. Each workstation can provide information quickly to the wing battle staff and anyone else on the network that needs it. The minimum bandwidth of 512K baud allows rapid transmission of even high-resolution imagery, such as weather, maps, intel photography, and base damage assessments (Science Applications International Corporation, 1990).

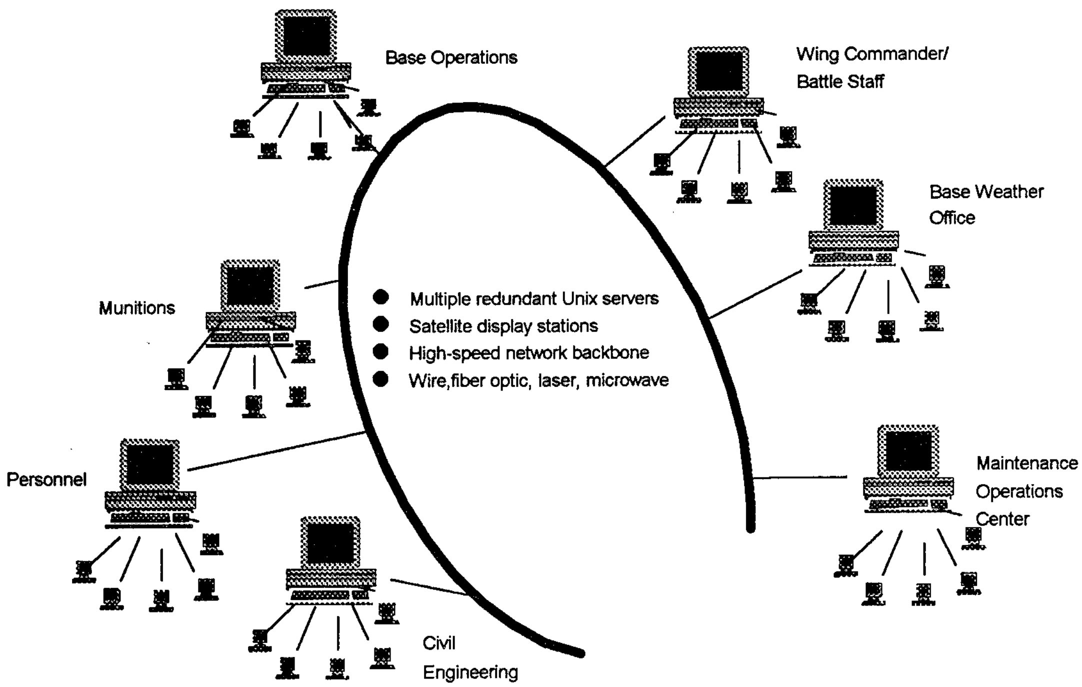

Figure 3
Wing Command and Control System (WCCS)

Using WCCS, the battle staff can query maintenance for mission capable status of aircraft; civil engineering for the condition of buildings, runways, and other base facilities; operations for aircraft and pilot scheduling information; and many other functional organizations. In current operations, the battle staff has to obtain this information through phone calls and hand delivery of reports.

WCCS is planned to be a home base as well as a deployable system, which allows it to play a major role in providing a dependable information flow during a contingency situation. The communication links at the home base will generally be standard copper or fiber optic cable, whereas WCCS in a deployed location will often be based on laser or microwave links if a network infrastructure is not in place. Deployed WCCS will be linked by satellite for electronic downloading of Air Tasking Orders. In addition to the current WCCS software applications in development, the WCCS network infrastructure is an important capability in itself. With a high-speed network linking together all base functional organizations in an open systems framework, next generation applications can be developed with the data distribution channels already in place. ECLiPSE can take advantage of this existing network infrastructure.

Problem Areas

Great strides are being made through the implementation of new and upgraded planning systems. However, many of the underlying limitations associated with contingency logistics planning remain unchanged. **Planning centers on a static UTC, manual calculations, and deliberate planning.** The results of the literature search, followed up by interviews, supported the findings listed below.

- **Current wing logistics planning/execution information systems are "human-in-the-loop" intensive, unintegrated, and unreliable at execution.** Although IDS will allow for automated entry of much of the information that (evidenced by Desert Storm) requires a great deal of manual pencil work and rework, it does not reduce the number of tasks that must be accomplished at execution time. When changes occur in the plan, the process of tailoring UTCs is still a "stubby pencil" process. The logistics planner is the integrator of the "raw" data which describes the deployment location and its associated operational requirements. Many of the subjects interviewed noted that computer communications lines from MAJCOM to base level were barely adequate to support deliberate planning, and that COMPES was not effective during the execution phase. These observations were borne out by reported lessons learned from Desert Shield/Storm (Hagel, 1992). For example, telephone taskings were common and were often inconsistent with **later** published versions of the TPFDL.

- **Much of the information that wing planners need to accurately tailor UTCs in short-notice situations is either not available or not accurate.** Information on the airfields being deployed to (including visibility into War Reserve Materiel (WRM)) during Desert Storm was considered inadequate (Hagel, 1992). Scheduling of airlift aircraft was often so unpredictable that some bases referred to "aluminum hailstorms" when airlifters arrived in large groups with no notice (Hagel, 1992). Also, the types of aircraft arriving were often different than expected. This required load planning to be re-accomplished with tools not designed to cope with the range of airlifters encountered.

- **Even if all of the information needed to accurately tailor a UTC at execution were available, the large volume of information would make it very difficult for wing logistics planners to accurately replan a deployment in a short time.** There is just not enough time to manually perform the desired calculations. No tools exist to support "what-if" analyses based on the anticipated tasking. Many aircraft parts were apparently in overabundance at the deployed sites, but other items were in short supply. These included serious initial shortfalls in munitions, support equipment spares, and chemical warfare equipment.

ECLiPSE VISION

The problem areas identified in this preliminary ECLiPSE study can be summarized as a lack of accurate and timely data, and a lack of time to adequately process that data to meet required deployment time lines. ECLiPSE provides a vision of state-of-the-art information systems, AI, simulation, and communication systems to help solve these problems by making useful information available during deployment planning and execution. This task identifies three projects that comprise the ECLiPSE vision: the Deployment Information & Support Environment (DISE), Unit Type Code Development, Tailoring, and Optimization (UTC-DTO), and Logistics Analysis to Improve Deployability (LOG-AID).

Deployment Information and Support Environment (DISE)

DISE comprises two distinct parts. The first part is a centrally located information system called the Deployment Knowledge Base (DKB). The DKB will provide fast access to audio, visual, and textual information pertaining to potential deployment sites. It will provide information such as site-specific maps, site- and region-specific lessons learned, airbase infrastructure data, and information on local suppliers of off-the-shelf resources. The DKB will be an important part of the solution to the logistics planner's problem of inadequate and inaccurate information during crisis planning and execution

Although information from UTCs and TPFDDs will be much easier to access electronically as part of the new systems currently under development, additional information useful for tailoring UTCs for specific scenarios is not included in the existing development plans. Much of this data resides in the WWMCCS in a variety of different files and applications. However, this information is very difficult to access in the field because of the low data transmission rate and unreliable connections to WWMCCS. A good example of the type of information that is difficult to access and is very useful for UTC tailoring is the AAFIF.

The AAFIF contains detailed information on more than 40,000 airfields worldwide which might possibly be used for different contingency operations. For example, information provided includes local aviation fuel supplies; runway, taxiway, and parking area characteristics; communications capabilities; and services available in nearby towns or cities. The degree of availability of a variety of different items at the specific deployment site could drive significant additions or deletions to numerous UTCs.

Currently, access to the AAFIF through WWMCCS is a painfully slow process which can take several hours to download complete information on one location. In addition to slow access due to communication line limitations, several groups interviewed by the study team (including HQ USAF/LGS, the 366th, and the 906th) questioned the accuracy and thoroughness of the WWMCCS AAFIF.

The disadvantages of WWMCCS will disappear with the implementation of the DISE DKB. The DISE DKB will provide fast user access and rapid availability and

update of new information. Conceptually, the DKB will be distributed and made available to every Air Force unit through satellite links and wide area networks. Users will have the capability to query and edit the DKB from both remote and local stations. The design phase for the DKB will include identification of **all** types of data that might be useful to deploying AF unit planners. In addition to the data elements currently available in the AAFIF, the DKB could include maps, site photographs, real-time and projected weather information, WRM assets, host nation agreements, logistics information on units already deployed, and transportation schedules.

The amount of information available in the DKB could quickly overwhelm the best of planners if it is not presented in an organized, easily navigated application. For the information to be useful, a good user-centric design will be imperative to the DKB interface. Planners do not have the luxury of being Internet surfers. The DKB will have to leverage the best of user interface design in combination with the technologies of expert systems, multimedia, intelligent databases, and distributed information systems.

Populating the DKB with data is a different problem but no less demanding. Without the correct data, the best interface is useless. The second component of DISE consists of the input systems for populating the DKB. Currently, the two input components include MAFIS, and ALLRS. In addition to these, other component applications could be designed in the future which could easily be inserted into an open systems design of the DKB. One further potential system currently under consideration for addition to DISE is the Beddown Planning Tool (BPT), which will be discussed later in this report. Other areas to investigate involve the development of distributed collaborative planning tools (including videoteleconferencing and whiteboarding) and document management systems, which allow for scanning and cataloguing of important documents, which could include orders, plans, cargo manifests, transportation schedules, and so forth.

Multimedia Air Field Information System (MAFIS)

The proposed MAFIS conceptual diagram is shown in Figure 4. MAFIS will be an electronic, portable system with the primary purpose of allowing site survey team members to record their observations directly into a computer. This alleviates the current process of delivering the handwritten survey to Defense Mapping Agency (DMA) for their quarterly update into the AAFIF. The data would be available immediately at the base doing the site survey in the new centralized database with high-speed data channels, whether this be within WWMCCS, the new GCCS, or a stand-alone database. The data could be transferred to this database via satellite to avoid any lag time. A base-level component available from any WCCS terminal would allow the selection of a particular airbase and viewing of its information through a graphical user interface consistent with other WCCS functions. In addition to all the information about airfields contained in the AAFIF, MAFIS will provide maps, photographs, video, and audio associated with the different locations. This information is collected by the site survey team.

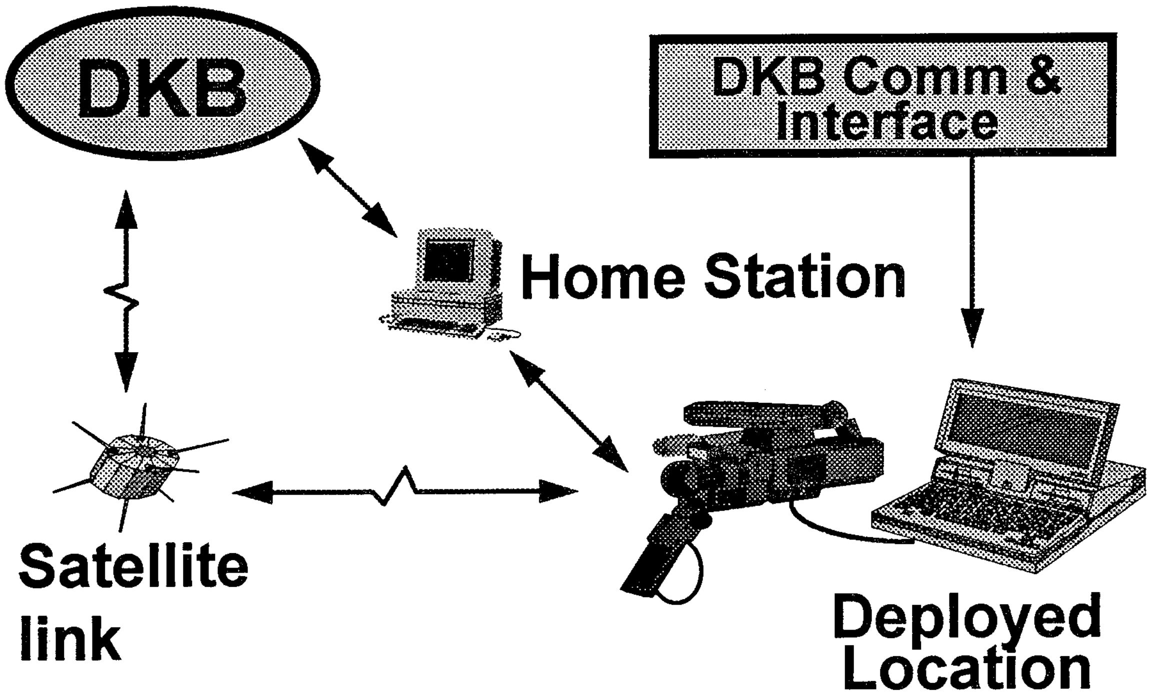

Figure 4
Multimedia Air Field Information System (MAFIS)

MAFIS could actually be employed and implemented in different ways. Depending on the location of the deployment, MAFIS will be connected to the DKB either by satellite link or land network connection. In the future, deployments in friendly countries may allow for base network connections back to the Continental United States (CONUS), while forward deployed locations will probably not be able to count on network reliability due to potential adverse enemy action. Members of a survey team might collect data separately during the day, then return to the satellite transmitter to upload to the DKB. Alternatively, each member's MAFIS unit could be equipped with a wireless local area network (LAN) interface card. This would allow immediate transmission from any team member throughout the day to a central server PC unit, then through the single satellite transmitter to the DKB. Within a year, wireless LAN technology should reach the point of enabling such a PC system for less than $200 each.

MAFIS usage would not be limited to the initial survey. It could also be deployed with the unit, providing valuable time-critical information back to the DKB and home base as conditions change. Videoteleconferencing could be implemented using the MAFIS hardware, possibly by integrating commercial off-the-shelf (COTS) software.

Technologies required for MAFIS involve the integration of multimedia information with intelligent databases over wide and local communications networks. Using these technologies, MAFIS will significantly improve the speed of transmission and quality of data about deployment locations.

Automated Lessons Learned Recording System (ALLRS)

ALLRS will provide for the collection of quantitative data involving problems experienced during an in-theater tour, and the recording of user-specified problems and solutions. This capability provides a real-time look at the conditions at deployed locations, enabling units on subsequent deployments to the same or like locations to make faster, more accurate plans. Figure 5 depicts the architecture that will enable this to happen.

ALLRS will be connected as a node on a LAN at a deployed base. This network infrastructure will be part of the environment currently envisioned for WCCS, LOGMOD-B, SBSS, or something yet to be defined, which will provide basic connectivity to the base. ALLRS will consist of one or more workstations running an operating system and user interface that will provide it with a look and feel very similar to all other applications on the deployed open systems network. ALLRS will employ a database management system, either one of several commercial object-oriented systems or the Oracle Relational Database Management System (RDBMS) Version 7, which is already being used for WCCS. This database will be used to store all the lessons learned data collected.

ALLRS could be implemented on an existing open systems network, whether it is WCCS, LOGMOD-B, or SBSS. Different ways of obtaining the desired data automatically from the network are described in Appendix A, and these modes can be combined to obtain a balance between utility and ease of implementation. Automatic collection of data is useful in monitoring many different types of information that will be very interesting to the person who will be in the same spot three months in the future, **without requiring full-time data entry people at the deployed site**. Once a deployed network is in place, an ALLRS node will just sit on the network and listen to the information traffic, requesting pieces of data it has been set up to retrieve. As soon as the local network has recorded the information, ALLRS will automatically transfer to the DKB the quantities and status of spares, support equipment, munitions, and vehicles. Daily weather information and forecasts from wing weather servers can be transmitted. Operational information on sortie generation, aborts, completion, and mission success could be captured as well. This information is valuable not only to the next deploying unit but to the currently deployed unit. The home base can monitor supply status in real time and help expedite the resupply process, taking some of the burden from the deployed supply personnel.

In addition to the automatic collection mode, ALLRS will include a client interface that will allow any other human-attended node on the deployed network to connect to the ALLRS lessons learned server. With a mouse click, users on the base network will be able

to bring up a user interface that allows them to enter lessons that they **are in the process** of learning. Instead of waiting to file "after-action" reports, problems can be entered as they occur, time-stamped, keyworded, and separated by functional and geographic areas. During Desert Shield/Storm, many problems never made it into the Joint Universal Lessons Learned System (JULLS), but were buried in trip reports or people's memories, to be manually dragged out later by organizations doing studies of "what happened?" (Hagel, 1992). Not only will the ALLRS client program capture more of the problems encountered, it will provide for the possibility of cross-referencing the user-entered

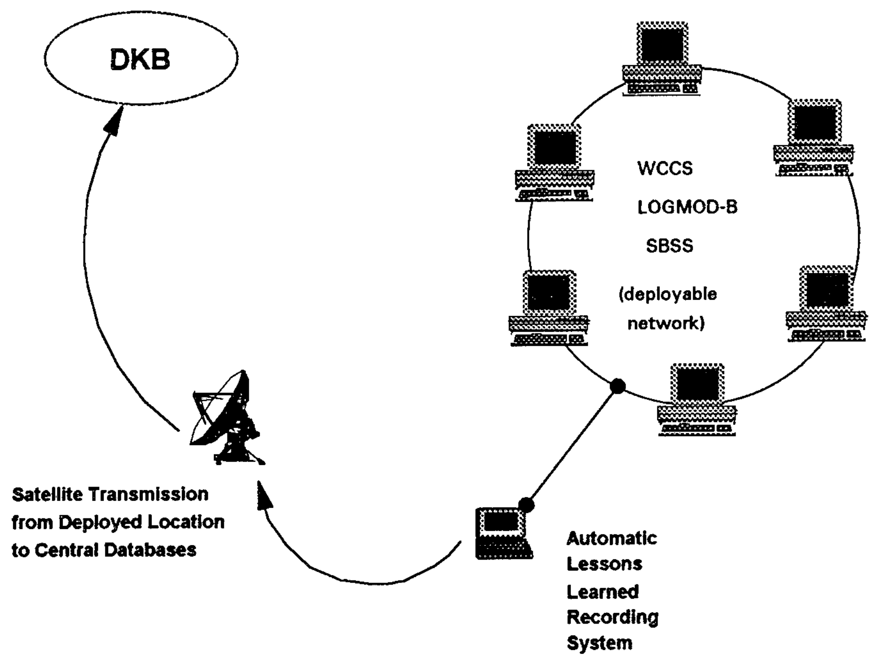

Figure 5
ALLRS as a Node on a Deployable Network

problem with the automatically collected data from ALLRS, potentially helping to find the root cause much faster.

Finally, ALLRS can be used effectively at home bases. It can help a unit find problems with its normal processes and rapidly address them. In addition, information from different home bases can still be fed into the central DKB where other units can see it. These other units can find information on problems someone else has already solved, or information from a base that might be similar to the anticipated deployment location.

Unit Type Code Development, Tailoring, and Optimization (UTC-DTO)

UTC-DTO comprises of two subcomponents: an automatic UTC development and tailoring capability and an automatic palletization optimization system. These tools will provide a critical improvement to the rapid planning process by analyzing the information

in the DKB and making recommendations to the planner. This "sifting" of the DKB is necessary to keep the planner from being saturated by too much good, but raw, information. The development and tailoring capability component will help deployment planners rapidly develop or tailor UTCs for specific deployment missions. During a crisis, this component will highlight all the items in the tasked UTC that need to be tailored out of the package by using information stored in the DKB along with other important pieces of information as inputs to the automatic tailoring process. The automatic palletization optimization system component will help unit personnel palletize cargo by automatically generating near-optimal pallet arrangements (smallest cube vs. maximum weight and within aircraft dimensional and center of gravity limitations) based on the tailored UTCs.

Development and Tailoring

The development and tailoring system, shown in Figure 6, has two primary functions:

1. providing real-time site-specific information to the wing- and squadron-level contingency planner, and
2. automatically tailoring UTCs based on this information.

Information obtained through the DISE system would be provided at the UTC-DTO workstation. To aid in planning specific deployments, the planner would have rapid access to all site survey information, as well as lessons learned on previous deployments. This information would be accessed by selecting either specific locations (airfields), regions, or climatic conditions, and by using the keyword-indexed retrieval and free text search functions. As stated previously, electronic collection of this data, as well as high-speed delivery to the field, is critical to provide current information. Planners would be able to look at detailed information on the specific base for which they are planning a deployment, or similar bases in cases where the target base has not previously been a "deployed-to" location. The information would be provided in different views, from maps and hyperlink photographs of significant airfield features, to fixed format windows giving standard airfield information such as runway descriptions, fuel capacities, medical facilities, and the like, to narrative windows describing past problems and solutions encountered.

All the information on the UTC-DTO workstation could be used to support manual tailoring of deployment requirements, as well as to support the generation of reports relevant to various functional organizations. In addition, the UTC-DTO system will have the capability to load standard UTC packages and use MAFIS and ALLRS to automatically provide tailoring recommendations. After specifying the desired UTCs, planners would select a specific airfield and optionally a lessons learned database to be loaded into their workspace. UTC-DTO would take relevant parts of the two databases loaded and determine their effects on the UTCs selected. Much of the data in MAFIS and ALLRS can be associated with rules to govern quantities of manpower and materiel. New UTCs would be created and displayed to users in a context-sensitive editor, with

recommended changes to the standard UTCs highlighted. Planners could look at

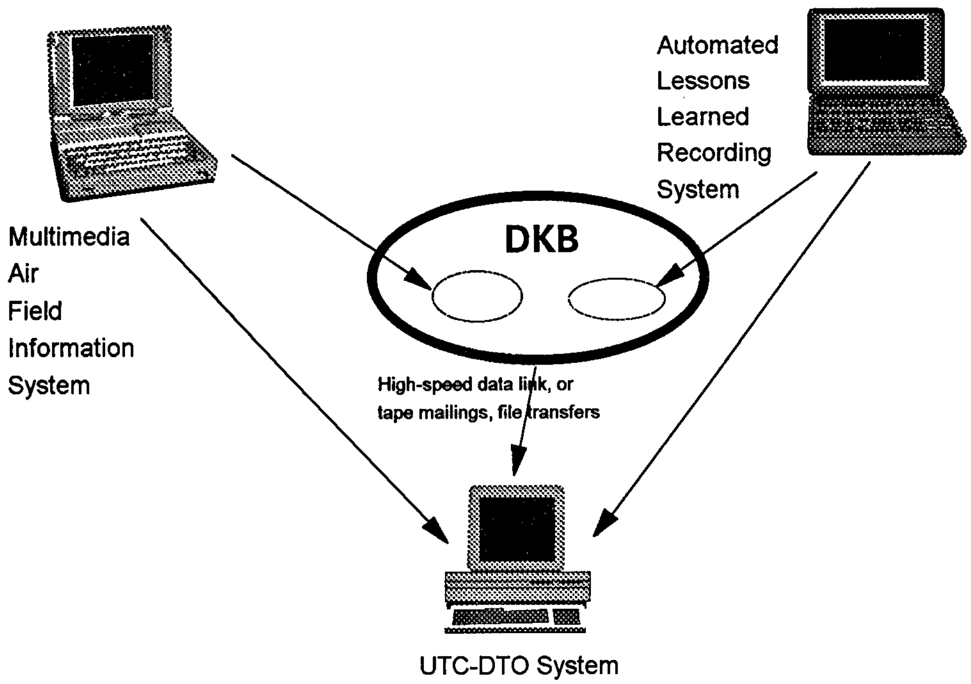

Figure 6
Unit Type Code Development, Tailoring, and Optimization (UTC-DTO)

recommended additions or increases (highlighted in blue) and recommended deletions or decreases (highlighted in red) in equipment and manpower levels, and decide whether to accept all or part of the recommended tailoring. The capability would exist to also add/delete requirements manually, based on the planner's experience, information in MAFIS or ALLRS which is not associated with a tailoring rule, or recommendations/directions from other sources. Once the automatic and manual tailoring is complete, the new UTCs will be transferred automatically to LOGMOD-B and MANPER-B for eventual uploading into the MAJCOM components of COMPES. The open systems network connection will also allow all functionals to view and potentially edit relevant parts of the tailored UTCs.

Pallet Optimizer

The pallet-optimization component of UTC-DTO is envisioned to be the next logical step in automated load planning. It will take the experience of the CALM system and extend it to allow expert load planners to set up rule bases for different aircraft. Given input cargo and personnel listings generated from the development and tailoring system, the pallet optimizer will use these rules to automatically generate optimal plans for the specific cargo on the 463C pallets.

Logistics Analysis to Improve Deployability (LOG-AID)

The ECLiPSE task has provided much insight into the problems associated with deploying large forces to distant locations. It has also generated research ideas (DISE and UTC-DTO) that can be exploited now to improve wing-level deployment planning. However, this task revealed just enough about the current problems associated with wing-level deployment planning to demonstrate that a much deeper analysis is required. LOG-AID will investigate wing-level deployment to further investigate and refine user requirements and desires for future deployment planning resources. The purpose of this study is to identify advanced technologies and processes that have the potential to improve wing-level (and wing equivalent units of the other services) deployment planning and execution, reduce mobility footprint, reduce deployment response time, and use mobility resources more effectively and efficiently. More specifically, LOG-AID will:

- build on the original ECLiPSE study effort and the HQ USAF Integrated Definition (IDEF) deployability study;
- further analyze Air Force requirements associated with deployment planning;
- analyze deployment planning processes of the Army, Navy, and Marine Corps;
- solicit user requirements for future deployment planning tools, systems, and processes; and
- suggest innovative processes and technologies to satisfy user requirements in the deployment planning arena.

The information gathered to support LOG-AID will come from (but will be not limited to) the original ECLiPSE Requirement Study, the HQ USAF/LGX IDEF deployability study, interviews with deployment planners (users) at the wing-level (and wing equivalent units of the other services), observations of wing-level (and wing equivalent units of the other services) deployment planners performing deployment planning (either during real-world deployments or base exercises), and a survey instrument which asks users for their requirements and desires for future deployment planning resources.

ENABLING TECHNOLOGIES

The efforts on this task involved studying several new technologies that could be beneficial in the ECLiPSE system. Areas examined include desktop videoconferencing with collaborative planning, case-based reasoning, satellite communications, and intelligent databases.

Desktop videoconferencing would greatly enhance the communication capabilities between airfield surveyors and any other location. With current practices, communications outside the airfield are sometimes very difficult because of a lack of suitable communication equipment on the site. Desktop videoconferencing capabilities built into MAFIS would allow for a reliable and consistent communications medium that is independent of on-site equipment. Therefore, a study on desktop videoconferencing systems was performed. An analysis of several different products available for Macintosh, Windows and Sun systems was completed. Different capabilities were examined, including communication functionality, cross-platform compatibility, conformance to videoconferencing standards, the number of allowable conference participants and information-sharing capabilities (e.g., a shared whiteboard, file transferring and application sharing).

MAFIS also depends on the availability of easily portable computers and satellite communication equipment. A study was performed on the SPORTS and ImageHawk systems, two products that provide easily portable data collection and transmission capabilities. A satellite communication system called International Marine Satellite version B (INMARSAT-B) was also examined. This system provides global coverage and is also easily portable. It allows for high-speed transmission of data, including faxes, audio, and video clips. Videoconferencing is also possible through an INMARSAT-B connection.

ALLRS requires a method of storing lessons learned and determining which previous lessons apply to a current mobilization. An AI technology called case-based reasoning is well-suited to this task. This methodology allows previous experience to be cataloged into separate cases. These cases are then stored in a central database. When a new situation arises, it is compared to each case in the database. The solutions to the cases that most closely resemble the new case are recommended. A solution to the new case can then be recommended, and the new case is added to the database. This allows the database to continually grow, thereby allowing the system to learn and become more proficient at correctly solving problems previously unencountered.

A crucial factor to the successful operation of the UTC-DTO system is the ability to extract meaningful information from different databases such as WWMCCS and GCCS. Traditional database functionality has proven to be very limited in providing useful information. Therefore, a study was performed on the relatively new concept of intelligent databases. These data bases combine traditional database functionality with technologies such as object-oriented programming, expert systems, hypermedia, and on-line information retrieval. The result is a methodology that allows for the easy extraction of

information from large, complex databases. This ability is even more important to systems such as ECLiPSE that directly support decision-making tasks.

Desktop Videoteleconferencing

Videoconferencing is a relatively new technology that provides full audio and video capabilities to conference members at the source and one or more remote locations. Speakerphones and conference calls are commonplace in today's working environment, but they lack the live video component. Non-verbal communication can now be achieved, and visual displays such as charts or models can be conveyed without resorting to a fax machine or verbal descriptions. Quite simply, videoconferencing is "the next best thing to being there."

Videoconferencing capabilities have recently been introduced to desktop computers. One benefit is that conference members do not have to go to a specific location equipped with a videoconferencing system. Instead, members can participate in a videoconference right at their own desks. Perhaps an even greater advantage lies in the fact that members of a desktop videoconference can share data. For example, one member might have a chart he wishes to show to the others. With this capability, the chart would show up on any or all of the others' screens through a shared whiteboard. Some software packages have a capability called application sharing. This allows any participant to view and edit data from a remote machine. Thus, if one member has a WordPerfect document, the others can use WordPerfect to view and edit the document even if the application is only installed on the host machine.

Since desktop videoconferencing is such a new technology, there currently are no standards that fully define desktop video capabilities. Standards such as H.320 are designed solely for video and audio transmission; therefore, they do not provide specifications for the data transfer necessary for shared whiteboard and application-sharing capabilities. Consequently, most products examined use a proprietary format that prohibits interoperability with other systems, so a Sun SPARCstation with ShowMe cannot engage in a videoconference with an Apple Macintosh running Cameo. Some companies have instead made versions of their products that run on different platforms. For example, InSoft makes different versions of Communique! for Sun workstations and PCs running Windows. The video and audio conferencing capabilities are there, but other features such as application sharing are not.

There are two modes that videoconferencing systems operate under, LANs and phone lines. When phone lines are used, they will be Integrated Services Digital Network (ISDN), Switched 56, or analog. Many products operating under Switched 56 or analog use two phone lines for videoconferencing, one for the video signal and one for audio.

There are many desktop videoconferencing systems available for the different computer platforms. Several of these are described in Appendix B.

Portable Computing/Satellite Communications

The key element of MAFIS is a computer system capable of capturing textual, graphical, video, and audio data. The system must be easily portable in order to minimize the encumbrance of the airfield survey team members. Also, the system must have a way of easily and quickly transmitting the accumulated data to a central location for inclusion in a major database. Due to the global variety of potential MAFIS sites, the system must be able to communicate through satellite links since other means may not be possible. INMARSAT-B is a widely used satellite communication methodology that is very applicable to ECLiPSE. INMARSAT-B's flexibility and high transmission rates allow for capabilities such as data transfer (audio and video data included), faxing and videoconferencing. A large network of satellites and ground stations provide global coverage. This system is discussed in depth in Appendix C.

TASC offers two products, SPORTS and ImageHawk, which provide the capabilities mentioned above. Both are designed to be remote-location data-collection tools that have the capability to communicate through an INMARSAT system. These products are discussed in Appendix D.

To automate the Standardized Airfield Survey Checklist, extensive database software needs to be written. This will probably involve the use of object-oriented databases to develop a fully operational MAFIS. The difficult items, such as setting up communication methods, designing the physical system for portability, and incorporating true multimedia capabilities, have been successfully demonstrated by the SPORTS and ImageHawk products.

Case-Based Reasoning

ALLRS needs a method to generate new lessons learned "records" and store them in the lessons learned database. UTC-DTO needs a way to scan the Lessons Learned Data Base (LLDB) and retrieve any lessons that are comparable to the current situation. Both tasks are difficult; however, an AI technology called Case-Based Reasoning (CBR) has proven to be very proficient at performing these tasks. Appendix E provides a detailed explanation of the CBR technology.

CBR systems are useful when the problem domain is not totally understood. This is the case with contingency planning because there are so many factors involved that it would be extremely difficult to develop a sufficient rulebase. The capabilities of operating with missing data and handling non-numerical data also make CBR a viable approach for ECLiPSE.

The volume of data that will be entered into the ECLiPSE system mandates a technique that allows for simple data entry. As discussed in Appendix E, statistical pattern recognition, expert systems, and neural networks do not offer easy ways to add data to the system. CBR systems, on the other hand, allow users to add information to the system

through data entry forms. The new case will be indexed and become part of the LLDB for future use.

A CBR system can be integrated into ECLiPSE so that it is accessed by both the ALLRS and UTC-DTO subsystems. An initial LLDB must first be generated. After it is put in use, new cases will be regularly added through the ALLRS system. As contingency planners submit lessons learned to ALLRS, the lessons are added and indexed for future retrieval.

When the UTC-DTO subsystem is being used to plan a mobilization, the contingency planners will input the features of the situation into the CBR system. Any cases that suitably compare with the current one will be displayed, showing the results of previous lessons learned. These results will contain suggested additions and deletions to standard UTCs that previous contingency planners deemed appropriate. Planners can then modify a retrieved case to match the current one. This new case will then be entered into the LLDB.

As cases are added through both the ALLRS and UTC-DTO subsystems, the CBR system becomes more powerful and the likelihood of retrieving an exact match continues to increase. Therefore, the need to modify retrieved cases that are close to the input situation is reduced. Eventually, case modification will only need to be done on rare occasions. Quite simply, a CBR system used in ECLiPSE will give contingency planners access to the experience of every person that has previously planned and executed a mobilization.

Intelligent Databases

Intelligent databases can loosely be defined as databases that manage information in a natural way, making that information easy to store, access, and use (Parsaye et al., 1989). This concept has grown out of a need for end users to get more effective use out of information systems. Discussed here are some limitations of the current database technology, and ways in which intelligent database concepts overcome some of those limitations.

As the amount of information contained in one "store" increases, it becomes increasingly difficult to use that information efficiently. Similarly, it becomes increasingly difficult to verify the accuracy of the information. Storing information in computer databases decreases the level of this problem. Data in databases can be accessed by queries based on values contained in individual entries or keywords associated with those entries. Once information of interest is found, it can be retrieved immediately and presented to the user. Also, integrity checks can be performed on databases to ensure certain simple errors are not present in the data. Traditional databases, however, only begin to address the problems of usability and data integrity of large information systems. Most modern information systems use relational database management systems (RDBMSs) which are limited to some very basic capabilities.

Database integrity support is generally limited to referential, non-null, and type. Referential integrity prevents one database entry from referring to another entry which does not exist. Non-null integrity prevents certain fields from being left blank. This is usually known as "entity integrity" (Elmasri & Navathe, 1989) because it usually applies to primary keys. Type integrity prevents information of the wrong type from being stored in a database field (e.g., text data cannot be stored in a numeric field). It would be useful for the database to enforce more sophisticated integrity constraints. A simple example might be to limit the range of valid values for a runway length to positive values. An even more sophisticated capability might allow the database to discover and suggest its own integrity constraints.

Queries are limited to SQL or Query by Example (QBE). Both query types are limited to relatively simple queries such as, "Select airbases where runway length >= 5000." Although the queries may access multiple tables and contain compound boolean expressions, they must explicitly define the information that should be returned. A more useful query language might allow queries such as, "Select airbases where bombers are supported." The database would then determine the characteristics that are needed for bomber support and which airbases satisfy those requirements.

RDBMSs do not directly support viewing and traversing the information they contain. They simply store data and return the data requested by queries. The only views they are aware of are flat sets of records. Most applications must implement predefined routes for traversing the database. Ideally, a user should be allowed to traverse and view information in a database in a manner that is natural to them.

Only a limited set of data types are supported by RDBMSs. Traditionally, information stored in databases is either numeric, character, or a special case of one of those two (e.g., a date is a special character field). Support for data types like images, audio, and video is very limited.

Capabilities that go beyond the limitations listed above are not directly supported by RDBMSs. When needed, these capabilities must be implemented by the application programs accessing the database system. This causes application programs to re-implement similar capabilities. It also causes inconsistencies. For example, one application may constrain airbase runway length to positive values, another may constrain it to values greater than 100. Furthermore, when constraints change, changes to the application are usually necessary.

RDBMSs continue to evolve; however, they still fall short of providing the functionality required by many applications. In an effort to address the restrictions of RDBMSs, a concept called "intelligent databases" has developed. Intelligent databases represent a new technology for information management that has evolved as a result of the integration of traditional approaches to databases with more recent fields such as object-oriented programming, expert systems, hypermedia, and on-line information retrieval (Parsaye et al., 1989). The integration of these technologies would create an information

system that could offer users capabilities that go beyond the previously mentioned restrictions.

Current database engines do not encompass all the technology included in this definition of intelligent databases. At this stage, the intelligent database is more of a concept than a tool. However, the individual technologies are evolving to the point where they can more easily be integrated when developing an information system.

Object-oriented technology is evolving quickly. Object-oriented programming has already been integrated with database technology. There are many commercial object-oriented database management systems (ODBMSs); these systems primarily address three RDBMS limitations. First, they expand database integrity support. By encapsulating data and functionality, objects provide a natural place to implement complex integrity constraints that all data access must pass through. Second, they extend the data types. ODBMSs support complex user-defined types. Third, they allow direct links from one database object to another, thus allowing database traversal without constructing queries.

Expert systems have had moderate success in niche markets such as system diagnosis. Expert systems are now adding object-oriented capabilities. This creates the possibility of integrating expert system technology with ODBMS technology. Marrying the expert system's "knowledge base" of rules with the object language's class structure proves to be a natural and sensible approach (Bloor, 1993). This "marriage" would allow end users to add rules to the system. These rules could be used by the expert system to perform its traditional role processing the rules for data constraint and reasoning, thereby eliminating the need for all data constraints and logic to be programmed into the application.

Hypermedia is defined as the use of data, text, graphics, video, and voice as elements in a hypertext system. All the various forms of information are linked together so that a user can easily move from one to another. Hypermedia is among the fastest growing sectors of computer technology (Jovanovic & Mrdalj, 1993). Hypermedia and ODBMS technology closely parallel each other. Hypermedia allows links between information that is viewed; ODBMSs allow links between information that is stored. Implementing a hypermedia system on top of a ODBMS would allow users to traverse the database at will.

On-line information retrieval is concerned with the representation, storage, and accessing of information. One basic method of retrieval is to index information using keywords. This allows fast retrieval of information based on keyword selection. This usually requires manually entering keywords when information is added to the database. More advanced retrieval methods use automated indexing of information based on its content. Automated indexing is often based on statistical analysis of the information (Parsaye et al., 1989). This eliminates the need for users to define keywords for information entered in the system.

Intelligent databases do not currently exist as stand-alone tools. However, the technologies encompassed by the intelligent database concept can be used to overcome some limitations of traditional databases. Any large, complex information system should strive to integrate the technologies associated with the intelligent database concept to increase their usability. This is especially true of systems designed to directly support decision-making, such as ECLiPSE.

AREAS FOR FURTHER RESEARCH

This task provided a great deal of useful information about some of the current problems associated with wing-level deployment planning, initiated research of several systems that will overcome some of these problems (DISE and UTC-DTO), and demonstrated the need for a more detailed requirements study of the wing-level deployment process (LOG-AID). Due to time and money restraints, not all of the ideas that surfaced during this task transitioned into actual research projects. The two most noteworthy of these ideas are the Beddown Planning Tool and the Capability Assessor. The following paragraphs outline these areas, which are outstanding candidates for further research.

Beddown Planning Tool

The Beddown Planning Tool (BPT) will provide the capability to set up detailed plans for the deployment site. Site planners at deployed locations need to evaluate the effect on their base of having several units hosted as temporary tenants. Capt Wayne C. Foote (Foote, 1993) wrote about the steps in this process with regard to several different major areas: potential scenarios, augmentation, billeting, messing, civil engineering, maintenance, munitions, security, supply, fuels/fluids, transportation, and base actions. Many of the items that he urged be addressed involved procedures that should be put in place to ensure smooth operations during a deployment. Many of the other issues involved with planning for a large temporary tenancy can be enhanced by the use of computers. The BPT specifically is envisioned to allow the graphical layout of a base and the considerations that involve spatial planning to be accomplished on a computer. Some of the plans normally done manually involve aircraft parking, tent cities, messing facilities, building conversion to alternate uses, aircraft shelters, hot-pit points, munitions storage and assembly areas, security points, perimeter defense, aircraft tank buildup locations, additional supply storage, and fuel bladder locations. All of these could benefit from the use of computer technology, in terms of both faster planning and better plans.

At least one effort is currently in development to address some of these considerations. CRISIS, sponsored by the USAF Academy, has a civil engineering focus (Royer et al, 1990). It allows the graphical construction of different elements of an airbase for a two dimensional, top-down view. CRISIS is an application layered on top of AUTOCAD, a sophisticated Computer-Aided Design software package, which sells for

approximately $4000. Efforts are currently underway to port CRISIS to an open systems environment, where it will presumably be independent of AUTOCAD.

CRISIS allows specification of runways, parking areas, and buildings. It also provides the civil engineer with the capability to flag bomb craters, fires, and other problems around the base. Other users can use the Civil Engineering data as status information.

While CRISIS provides a good tool for civil engineers, there are many facets of planning for arrival of deploying units that it does not encompass. Also, it currently lacks a three-dimensional (3-D) visualization of the layout that is developed. Its interface is very Computer Aided Design (CAD)-like, which may be hard for the average logistics planner to use. An ECLiPSE BPT is envisioned to be a graphical application which will provide help in laying out and evaluating plans for accommodating deploying units. It will provide capabilities similar to CRISIS for runways, parking areas, general buildings, and emergency areas. It will also add the capabilities to "drag-and-drop" tent-city "cells," mess facilities, and many others previously mentioned. These items will be available from a tool bar. The planner will typically start with a map of the base as it currently exists, and choose relevant items from the tool bar to place on the map. In the ideal system, image recognition techniques would enable the basic features on the map to be categorized and stored as database objects. In a less well-developed system, the user could overlay toolbar items manually onto the scanned-in map, photograph, or vectorized drawing. This second approach will be used for items that are not part of the existing base structure.

For example, if a deployed base receives notification that it will soon be hosting 24 additional F-16s, plans need to be made for parking and sheltering these aircraft. Just as significantly to the planner, arrangements must be made for living quarters for additional pilots, maintenance crews, staff, security police, and so forth. If there is not existing space in on-base quarters, contract quarters, or converted base facilities, tent cities will be constructed. BPT users will select the tent city icon from the tool bar and drop it as an overlay onto the base map in the desired location, where they could subsequently size it to fit the deployment needs. They will have the ability to enter and save attributes of each item constructed. For a tent city, appropriate attributes might be number of beds, need for air conditioning units, latrine facilities, distance from base perimeter, distance from work centers, and messing facilities. In a full capability BPT, planners will be able to enter the attributes for the tent city, and the system will query its database knowledge of the base, compare the specified attributes, and visually highlight good-fit locations on the base. The planner could then locate the tent-city in one of those locations, or override the recommendation and locate it somewhere else. The BPT might also generate reports on the degree of suitability of possible sites specified by the planner, if no sites completely match the specified tent city attributes. This report generation capability should be implemented using intelligent database techniques, discussed in more detail in the section on enabling technologies. Essentially, an object-oriented (either physically or logically) database will contain the raw information about the base. Between it and the user-selectable function to create a tent city will be a set of rules that evaluate the user-specified attributes against the raw data, to form a complex query. Planners in this

example are giving the database a profile of the kind of tent city desired, and the database determines whether it can create one according to rules regarding the profile. This type of database logic obviously involves more preparation than a conventional database. Instead of just inputting schema, the database designer must input sets of rules involving the creation, modification, selection, and deletion of objects.

Capability Assessor

The Capability Assessor will provide the ability to load tailored UTCs, and use them, combined with known assets at the deployed location, to perform simulations of unit flying operations. Scenario definition databases would exist for each flying unit and OPLAN portion it was tasked to perform, describing expected sortie durations and frequencies, types and configuration of aircraft for different missions, attrition, and procedures for aircraft maintenance. Maintenance procedures could be recorded as Logistics Composite Model (LCOM) databases, since most existing weapon systems have already been documented in this format. The Integrated Model Development Environment (IMDE) simulation environment (described briefly in Appendix F) has already been modified to convert LCOM database networks into simulation programs, so it will be used to construct simulations using these databases and the UTC listings. Results from the simulations can be displayed, reported, or used to iteratively tailor the UTCs, automatically running sensitivity analyses on selected line numbers and changing quantities as required. Results could be used as an SORTS reporting tool, taking into account the dynamics of logistics processes that are currently not modeled. The simulation function will have to be designed to be at the same level of user sophistication as the Dynametric Microcomputer Analysis System (DMAS), to assure its initial usability. This type of simulation will in general only be used for mission-critical equipment and personnel. However, a library of object-oriented simulations could be constructed with IMDE which would allow other parts of the tailored UTCs to be checked as well. Simulations to validate medical, messing, housing, and resupply operations could be developed and designed to take input directly from the UTCs and a specified set of scenario inputs. Some of these functions will be adequately suited to smaller, less complex simulations than the aircraft maintenance procedures, and can therefore be more efficiently modeled in stand-alone simulations. IMDE can be used to develop the models, and the Capability Assessor can offer the different planning organizations on the base network the capability to choose from a list of the developed models to find those relevant to their planning needs.

CONCLUSIONS

There is clearly much dissatisfaction with the current unit-level contingency planning tools, and a lot of anticipation for the tools that will be coming on line in the next year. The challenge of ECLiPSE, aside from its technical aspirations, is to fit into the evolving information architecture in a way that allows planners to use it as an easily accessible set of tools on the network. Based on the results of briefings to logistics planners after the development of the conceptual ECLiPSE components, there appears to be a good deal of enthusiasm for the ideas that have been proposed. In an era when the U.S. is sitting on the brink of contingencies all over the world (Haiti, Cuba, Bosnia, Korea, Rwanda, and Kuwait, to name a few) and experiencing sharply declining defense budgets, automated tools that can optimize, in practice, available resources are needed immediately. Technologies are maturing at a pace where the ECLiPSE components can currently be prototyped in the open systems environment and demonstrate their ability to aid the rapid deployment process.

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ACRONYMS AND ABBREVIATIONS

3-D	Three-dimensional
AAFIF	Automated Air Field Information File
AF	Air Force
AFLMA	Air Force Logistics Management Agency
AFLMC	Air Force Logistics Management Center
AFSC	Air Force Systems Command
AFSOC	Air Force Special Operations Command
AGE	Aerospace Ground Equipment
AI	Artificial Intelligence
ALLRS	Automatic Lessons Learned Recording System
AMC	Air Mobility Command
AMPS	Automated Mobility Processing System
API	Applications Programming Interface
BPT	Beddown Planning Tool
CALM	Computer-Aided Load Manifesting
CASE	Computer-Aided Software Engineering
CBR	Case-Based Reasoning
CGM	Computer Graphics Metafile
CLI	Compression Labs, Inc.
CMOS	Cargo Movement & Operation System
COMPES	Contingency Operation Mobility Planning & Execution System
CONUS	Continental United States
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
CRAF	Civil Reserve Air Fleet
CRISIS	Combat Readiness & Infrastructure Support Information System
DISE	Deployment Information and Support Environment
DMA	Defense Mapping Agency
DMAS	Dynametric Microcomputer Analysis System
DOD	Department of Defense
DKB	Deployment Knowledge Base
DS	Direct Send
DVE	Digital Video Everywhere
ECLiPSE	Enhance Contingency Logistics Planning and Support Environment
EM	Eavesdrop Mode
ESCAM	Enhanced SORTS Capability Assessment Module
FEC	Forward Error Correction
FPS	Frames Per Second
GCCS	Global Command and Control System
GEOLOCS	Geographic Locations

GKS	Graphical Kernel System
HP	Hewlett-Packard
IDS	Integrated Deployment System
IGES	Initial Graphics Exchange Specification
IMDE	Integrated Model Development Environment
INMARSAT	International Maritime Satellite
ISAAC	Integrated Simulation Assessment of Airbase Capability
ISDN	Integrated Services Digital Network
JCS	Joint Chiefs of Staff
JOPES	Joint Operation Planning and Execution System
JTF	Joint Task Force
JULLS	Joint Universal Lessons Learned
LAN	Local Area Network
LCOM	Logistics Composite Model
LLDB	Lessons Learned Database
LOG-AID	Logistics Analysis to Improve Deployability
LOGDET	Logistics Detail
LOGFOR	Logistics Forces
MAFIS	Multimedia Air Field Information System
MAJCOM	Major Command
MB	Megabyte
MCU	Multipoint Control Unit
MDC	Maintenance Data Collection
MFEL	Manpower Force Element Listing
MTN	Maintenance Task Networks
NITF	National Imagery Transmission Format
ODBMS	Object-oriented Database Management System
OPLAN	Operational Plan
OPSMOD	Operations Module
OSE	Open Systems Environment
PC	Personal Computer
PHIGS	Programmer's Hierarchical Interactive Graphics System
PM	Poll Mode
QBE	Query By Example
R&D	Research & Development
RDBMS	Relational Database Management System
RF	Radio Frequency
RPC	Remote Procedure Call
SAC	Strategic Air Command
SBSS	Standard Base Supply System
SORTS	Status of Resources and Training System
SPO	System Program Office
SPORTS	Second-generation Portable Remote Telecommunications System
SQL	Structured Query Language
TASC	The Analytic Sciences Corporation

TCP/IP	Transmission Control Protocol/Internet Protocol
TPFDD	Time-Phased Force Deployment Document
TPFDL	Time-Phased Force Deployment Listing
UIC	Unit Identification Code
UIP	User Interface Prototype
USAF	United States Air Force
UTC	Unit Type Code
UTC-DTO	Unit Type Code-Development, Tailoring, and Optimization
WABI	Windows Applications Binary Interface
WAN	Wide Area Network
WCCS	Wing Command and Control System
WMP	War Mobilization Plan
WRM	War Reserve Material
WTI	Workstation Technologies, Inc.
WWMCCS	Worldwide Military Command and Control System

APPENDIX A

POTENTIAL DATA COLLECTION MODES FOR AUTOMATED LESSONS LEARNED RECORDING SYSTEM (ALLRS)

Three potential "modes" for collecting deployed lessons learned information are envisioned. These are called Eavesdrop, Poll, and Direct Send. Each has potential applications for obtaining information from a decentralized networking infrastructure which will be provided to some extent by WCCS and/or LOGMOD-B. The different modes vary in the selectiveness of their extraction of data, and correspondingly in the amount of information they are required to know about other network applications. Each is discussed briefly below.

In the Eavesdrop mode (EM), ALLRS will listen to all traffic on the network and determine what to save as significant lessons learned information. EM requires at least some analysis of every packet on the network, although many may be ignored after initial screening based on sender address and type of information contained in the message. EM will be the most technically challenging mode of the ALLRS automatic collection to develop, since it requires low-level network programming, a high rate of processing of packets, and a detailed knowledge of all potential WCCS packets of interest. WCCS packet descriptions are required in order for ALLRS to know which packets to ignore and what parts of the remaining packets to collect, as well as where to put the collected information in the database. EM has the advantage of requiring little or no active knowledge of ALLRS by other WCCS nodes. In the development phase of ALLRS, this would be advantageous in not requiring modifications to WCCS software modules to make them "ALLRS-aware."

Poll mode (PM) automatic collection provides the ALLRS stations with the capability to query individual WCCS database nodes at a specified frequency for desired information. PM is more intrusive into WCCS than EM, since it generates traffic on the WCCS network, and requires processing time from database servers on the network to respond to its queries. As an advantage, PM requires a much lower processing rate on ALLRS for longer query intervals. Only packets from the database queries need to be analyzed, and these can be processed at a client-server SQL level instead of the network layer programming level required for EM.

The use of EM collection would be advantageous if a complete time history of certain parameters were desired. For example, the specific changes made to the flying schedule might be monitored to determine what factors are most important in day-to-day scheduling of flying operations. Every time the flying schedule changes (takeoff time, mission abort, pilot change, in-flight turn, etc.), ALLRS picks this off the network and records it. This kind of time history might be useful as a "lesson learned" to the currently deployed unit as well, helping to identify scheduling problem trends that might be easy to correct if the likely causal factors could be pinpointed.

PM collection might be more advantageous for parameters that can be collected at a coarser level of granularity. For example, a daily report from the WCCS supply database

regarding parts availability might be adequate. The ALLRS station would automatically issue a request to the appropriate WCCS server on a daily basis, asking it to return the current supply inventory status, or maybe just delta quantities from the previous day's reports. Depending on the exact schema of the WCCS database, it may be possible to implement PM using standard SQL calls used by other WCCS information requesters, which would not require WCCS software modifications to accommodate this mode of ALLRS. PM has the additional advantage of allowing user-customized collection schedules of user-specified data by any authorized user capable of writing SQL queries. EM requires either a network programmer or development of a scripting language that would effectively mimic SQL functionality. EM time history data could be implemented by setting PM collection intervals as low as the expected change times of the parameter of interest. For example, aircraft availability could be requested every 15 minutes and probably provide all potentially interesting trend data. The tradeoff is some increase in network traffic while lowering the processing demand on ALLRS inherent in EM. An additional disadvantage of EM is that as the WCCS Oracle schema changes, the structure of each corresponding client-server data packet will change in a non-transparent way, making it more difficult to accommodate change to ALLRS to keep it "in-step" with WCCS. Finally, EM may not catch all changes desired to be collected, since data entered locally to a WCCS database may not be sent across the network if the redundant server is not on-line, or if the redundant server does not record time history data. An analysis of the effects of the additional network traffic generated by PM implementation should be accomplished to determine its significance.

A final option exists that would allow WCCS stations to "push" data to ALLRS. This might allow more flexibility to each WCCS functional area to specify for themselves which data elements generated at their station were important and should be captured in the Lessons Learned Data Base (LLDB). This Direct Send (DS) option has some of the advantages of the PM transfer option, with the additional disadvantage of requiring the WCCS development effort to comply with some interface control document specifying the methods of interfacing with ALLRS. Changes to ALLRS could potentially require corresponding changes in WCCS to maintain capability and even to avoid run-time errors.

Some combination of EM, PM, and DS may be desirable to implement ALLRS, with different modes used to satisfy different data requirements.

APPENDIX B

DESKTOP VIDEOCONFERENCING PRODUCTS

This appendix describes several desktop videoconferencing systems. Comparisons are made between the different capabilities of the products, with emphasis on compatibility with other systems and information-sharing capabilities. This appendix is broken down into three sections: Sun, Macintosh, and PCs running Microsoft windows.

Sun/SunOS

ShowMe (V.2.0)

ShowMe 2.0, produced by SunSolutions, is comprised of several separate packages that provide a full set of videoconferencing capabilities. It is based on the Motif graphical user interface and runs on SPARC stations over Transmission Control Protocol/Internet Protocol (TCP/IP) networks.

Video capabilities are provided through ShowMe Video. Video transmit rates are selectable by the user up to 30 frames per second. A camera is mounted on each user's workstation. A one-way conference feature that is also included allows participants without a SunVideo capture/compression SBus card to receive video images.

ShowMe Audio provides teleconferencing capabilities. The sound is played either through the computer's speaker or through headphones.

ShowMe SharedApp allows conference members to collaboratively run software applications, even if the application is only installed on one of the involved systems. SharedApp is Windows Application Binary Interface (WABI compatible; thus, it will run any WABI-supported Windows application as well as any X Windows System 11 application.

ShowMe Whiteboard provides a shared workspace where all users can concurrently display images, annotate images with text, enter a message, and so forth. Each user has a different colored "marker" so that it is possible to distinguish editions made by different people. Whiteboard supports 24-bit images, so high-quality graphics can be displayed. It is also possible to run several Whiteboard sessions on a single SPARC computer.

Unfortunately, ShowMe is not yet compatible with any other videoconferencing products; however, H.320 compatibility is planned for a future release. Versions of ShowMe for Hewlett-Packard and IBM workstations, as well as Intel platforms running Microsoft Windows or Solaris X86, will be available this year.

Communique! (V.3.0)

With two thousand licensed seats, InSoft's Communique! is one of the mainstream desktop videoconferencing products available for the Sun. Communique! offers full-motion color video, audio, file transferring, and text/graphics exchange through a shared whiteboard. The number of video conference attendees depends on hardware factors such as network load, but InSoft says there is a "logical limit" of ten. The software is available both separately and as part of a conferencing kit that contains a video board, a directional microphone, and a desktop video camera. Communique! has been ported to SunOS, HP/UX, AIX, and Solaris 2.3, and is soon to be ported to DEC's Alpha AXP workstations. Versions for both Windows and Windows NT are soon to be released. With the PowerPC coming out, InSoft is thinking about developing a version for the Macintosh.

Communique! runs best on a LAN or wide area network (WAN). ISDN and Switched 56 connections are also possible through a TCP/IP link.

Communique!TV is also included. With this package, input can be received from VCRs and cameras. This allows users to bring 8- or 24-bit gray scale images into the conference for viewing and editing through the shared whiteboard.

There are also two separate products available from InSoft, InSync and SHARE. InSync dynamically balances CPU and network loads, frame rates, compression ratios and sampling rates for optimal performance. InSync also allows users to manually set the frame rate and compression parameters. Data sharing is accomplished by the SHARE package. The application and data are local to one party, but all parties can concurrently view and edit the data.

Communique! currently uses a proprietary format to transmit video and audio data, but H.320 compatibility will be available later this year. Compatibility does exist between different platforms running Communique! Thus, Communique! on a Sun SPARCstation can be connected with Communique! on a Windows PC.

Application-sharing is only implemented in the UNIX version, so it is not yet possible to share applications from UNIX to Windows or Windows to Windows. InSoft is working on a method to share applications from the UNIX side to Windows running an X-Windows interface like PC Xview or Solaris X86.

Another example of InSoft's commitment to cross-platform functionality is the Digital Video Everywhere (DVE) architecture in all its products. The goal of DVE is complete hardware independence for both audio and video. Another factor that increases Communique's interoperability is the fact that InSoft does not build their own boards. Instead of using proprietary hardware, InSoft products support different commercially available boards. By July, InSoft will have an applications programming interface (API) for DVE that will allow third-party vendors to create cross-platform videoconferencing applications.

Paradise Software Video Conferencing (PSVC)

PSVC is produced by Paradise Software, Inc. It is strictly an audio/video conferencing tool; therefore, application sharing and whiteboard capabilities are not provided. Users can adjust frame speed, image quality, and window size of the video display. Video messages can be recorded on the hard disk through the UNIX mail subsystem to accommodate parties unable to attend the videoconference. PSVC does support multipoint conferences.

TCP/IP networks are used to handle the connections between parties. Instead of conforming to a standard such as H.320, PSVC uses a proprietary format in a similar way that ShowMe and Communique! do. Therefore, only those parties equipped with PSVC can join a conference.

At present, PSVC is only supported on Suns. Support for HP workstations will soon be available, and there are plans to support the IBM RS/6000. Unfortunately, Paradise Software has no plans to support either PCs or Macintosh computers.

Macintosh

BeingThere Pro

Intelligence at Large, Inc., produces BeingThere Pro. It is a LAN-based product that allows several parties to engage in a videoconference. It does not directly support TCP/IP connections but will work through a WAN extension for TCP/IP, such as AppleTalk Internet Router.

The software will handle up to ten parties, but four or five is the maximum for acceptable performance. Any more than that will cause the transmissions to be to slow, making video and audio annoyingly choppy. However, if the machine is equipped with a hardware codec (coder/decoder), the number of parties can be greatly increased and will only be limited by hardware considerations.

The Macintosh is currently the only supported platform. Versions for Windows and the PowerPC are being developed. There are no plans as of yet for a Sun version, but Macintosh is noticing a very large demand.

One drawback to this product is the lack of a shared whiteboard and an application-sharing capability. Instead, the package supports file-sharing. One party can edit the data while the other parties can only view the data. For another party to edit the data, it must be sent to that location through a file transfer capability. The drawbacks to this approach include wasted time and the necessity for all parties to have the appropriate software applications installed locally.

Cameo

Cameo is produced by Compression Labs, Inc (CLI). At present, it only supports point-to-point conferences, so only two parties can be involved in a videoconference. The audio is handled through a separate phone instead of through a microphone and speaker attached to the computer. Several different networks are supported, including Ethernet, ISDN, Switched 56, and analog phone lines using a modem. Cameo includes a shared whiteboard and provides file transfer capabilities.

At present, there is no interoperability with Cameo, so a person with Cameo can only engage in a videoconference with another person with Cameo; however, plans exist to change this. CLI is a member of a large consortium called Personal Communications Systems (PCS), which was started by Intel with the purpose of defining desktop video standards.

ShareView 3000

ShareView 3000 is produced by Creative Labs, Inc. ShareView 3000 provides full video and audio, an interactive whiteboard, and true application-sharing. The package includes two NuBus cards, a color video camera, a Plantronics Mirage headset, a telephone receiver, and software.

ShareView 3000 will be available for Windows-based PCs in the near future. It will be compatible enough with the Macintosh version to share video, audio, and whiteboard capabilities. Application-sharing will not be available between the two platforms at first, but Creative Labs does plan to offer the capability in the future. ShareView 3000 does not support H.320, thus it is incompatible with other systems. However, H.320 compliance should be implemented sometime in 1995.

ShareView 3000 uses a single telephone line to carry the video and audio signals. The system only allows point-to-point conferences, but multipoint capabilities will be available in the future. Audio and video clips can be saved for later use. ShareView 3000 allows a user to store ten minutes of video data on a single floppy disk.

ShareView 3000 has some additional features. ShareView Business Cards allow ShareView users to easily exchange photos or company logos. There is an integrated phone book that stores information about contacts. Incoming and outgoing calls are recorded by an automatic call log which allows users to review call statistics and conduct time-based billing.

Connect 918

NUTS Technologies, Inc., produces Connect 918. Up to three parties can participate in a videoconference. Connect 918 supports the H.320 videoconferencing standard: thus, conferencing with any other system that is H.320-compatible should be possible. Connect 918

supports ISDN and LAN connections, and will support Switched 56 and analog lines in the future.

Capabilities of Connect 918 include screen-sharing, file transfer, shared whiteboard, and video/audio recording and playback. Application-sharing is not possible. Instead, Connect 918 uses a file transfer technique similar to the one used by BeingThere Pro.

There are versions for both the Macintosh and Microsoft Windows. If a Macintosh and a Windows PC are both equipped with Connect 918, they have access to full video, audio, and the shared whiteboard. The Windows version is set to be released in June.

Visit Video

Visit Video is produced by Northern Telecom, Inc. It offers full video and audio conferencing capabilities as well as a shared whiteboard. Visit uses either ISDN or Switched 56 communication lines. Connectability through LANs and analog lines will be available in the future. Currently, it is a point-to-point system, but an eight-party bridge will be available in the future. There are no application-sharing capabilities, but Visit does allow file exchanging.

One attractive feature of Visit is its compatibility. There are versions for the Macintosh and Windows, and these versions are totally compatible with each other. Visit currently complies with the H.261 standard (a part of H.320) and will comply with H.320 in the future.

Microsoft Windows

AT&T Telemedia Personal Video System

The Telemedia Personal Video System seems to be one of the best videoconferencing products available for the PC. In a review of PC videoconferencing products, including PictureTel's LIVE PCS 100 and Northern Telecom's Visit Video (both of which are described later), *PC Magazine* listed the Telemedia Personal Video System as the Editor's Choice.

The system currently operates over ISDN and Switched 56 lines. LAN connectivity will be available near the end of 1994. By itself, the system only allows point-to-point conferences. However, multipoint functionality is available through a separate Multipoint Control Unit (MCU).

This system is currently the only Windows videoconferencing product that provides true application-sharing. Only two parties can share an application, even if an MCU is used. Multiparty application-sharing through an MCU should be available in the future. In addition, the system also provides an interactive whiteboard and a file transfer capability. The system is fully compliant with the H.320 videoconferencing standard.

PictureTel LIVE - PCS 100

PictureTel is one of the leading companies in the videoconferencing industry. Revenues in 1992 reached $141 million, and the company has approximately 45 percent of the market.

LIVE, or PCS 100, provides full-color video and full audio videoconferencing capabilities. The camera is designed to mount on top of a monitor or on a separate swivel stand. The stand is very useful when displaying documents. The camera is turned to face downward, allowing the user to display documents simply by placing them under the camera. Audio is handled through a separate speakerphone, although headsets are available.

LIVE operates over ISDN or Switched 56 connections. A multipoint bridge is available to allow several parties to participate in a conference. LIVE also offers shared whiteboard and file transfer capabilities.

PictureTel offers real-time application-sharing through its LIVE Share add-on product. This product provides certain capabilities that other application-sharing products do not have. First, bidirectional application-sharing allows both parties to simultaneously share separate applications. With remote control application-sharing, a remote site can invoke an application on another system, even when that computer is not in use. Lastly, LIVE Share allows users to simultaneously share multiple applications.

LIVE is one of the most compatible and upgradable of the videoconferencing products. It is fully compliant with the H.320 standard, allowing LIVE to connect with any competitive system that also supports H.320. Also, LIVE can easily connect with PictureTel's room-based, group videoconferencing systems.

InVision VideoConferencing for Windows

VideoConferencing for Windows is a software-only product designed to operate with i750-based Digital Video Interface (DVI) video boards. It is a LAN/WAN-based product, and is one of the few products for Windows that support TCP/IP and IPX connections. All hardware, such as the camera, microphones, speakers and video cards, must be purchased separately.

Application sharing is not supported as of yet. However, documents may be shared via an integrated product called Talk Show from Future Labs (not to be confused with the Talkshow videoconferencing product offered by Workstation Technologies, Inc., described later). This product provides shared whiteboard and file transfer capabilities. Talk Show should support application sharing by the end of this year.

The product is currently only a LAN/WAN system. Connections through ISDN or Switched 56 lines are possible, but only if they reside on another node on the network. By September 1994, InVision will support direct connection to ISDN, Switched 56, and analog lines. The September release will also offer H.320 compatibility.

The system only offers point-to-point connections. However, the next release will offer point-to-multipoint connections. This means that person A can concurrently connect with persons B and C, but B and C can only connect with person A.

Currently, Microsoft Windows is the only supported platform. However, InVision plans to develop a Macintosh version which should be available sometime in 1995.

VTEL 115

The VTEL 115 is a complete desktop videoconferencing system that includes a 486 PC, 15-inch monitor, VTEL's DeskMax cardset, speaker, camera with integrated microphone, and software. A separate document camera is available for viewing documents or 3-D objects.

The VTEL 115 operates over either ISDN or Switched 56 connections and can achieve data rates of up to 384 Kbps. VTEL is working on a LAN and TCP/IP capability. The system is compatible with other videoconferencing systems which support H.261.

One advantage of the VTEL 115 is the capability for application-sharing. This year, VTEL will integrate a commercially available collaborative computing program into the videoconferencing system. This will make VTEL one of the very few Windows-based products that support application sharing.

Multipoint videoconferencing is supported by a separate product, the MCU-II (multipoint control unit). It is initially configured for eight ports, but it can support up to twenty. Without the MCU-II, the VTEL 115 only supports point-to-point conferences.

A software-controlled video camera, called SmartCam, is available separately. The SmartCam provides features such as pan, tilt, zoom, eight preset positions, and image adjustment capabilities for higher image quality.

VTEL also offers other models, including the VTEL 117, which is identical to the VTEL 115 except that it comes with a 17-inch monitor.

Talkshow

Workstation Technologies, Inc. (WTI), produces Talkshow, a desktop videoconferencing system that is available for Windows, Macintosh, and the PS/2. Video is supported though a camera mounted on top of the monitor, and audio is handled through a speakerphone.

Talkshow is fully compatible across the three supported platforms. It is currently compliant with H.261, and will be compliant with H.320 sometime in 1995. Talkshow provides an interactive whiteboard.

Talkshow operates over Switched 56 and analog lines. ISDN communication will be supported in July 1994. WTI has just started beta testing an inband audio capability that will allow transmission of both video and audio data on a single line.

Talkshow is currently a point-to-point system. WTI plans to offer a multipoint videoconferencing capability in 1995.

Summary

The best-case scenario would be the capability to run full video, audio, a shared whiteboard, and true application-sharing in a multipoint conference regardless of the hardware platforms used. Unfortunately, desktop videoconferencing is such a new technology that all the desired capabilities are not available in one system.

At present, the H.320 standard is the only way that cross-platform videoconferencing is possible. Since there are no packages that are compatible with every platform, using different H.320-compliant packages for each platform seems to be the only way to achieve cross-platform videoconferencing. However, the H.320 standard is only designed for video and audio data, so there are no guidelines that specify how to implement capabilities such as shared whiteboards or application-sharing. As stated in the previous sections, there are products such as ShareView 3000 and Connect 918 that are built for different platforms. These packages provide for cross-platform video and audio, and in some cases a shared whiteboard. Unfortunately, there are no packages that provide cross-platform application-sharing.

Table B-1 depicts a visual comparison between the packages discussed. The shaded areas show which functions are available for each system. Only those capabilities that were available at the time of this publication are indicated.

InSoft's Communique! seems to be a good candidate for UNIX-based systems. It provides for multipoint conferencing, a shared whiteboard, and true application-sharing as long as the parties are operating under supported UNIX platforms. A Windows version will be available that is compatible (except for application sharing) with the UNIX systems. Also, H.320 compliance will be available this year.

SunSolutions' ShowMe is also a good possibility. It provides all the desired functionality for UNIX-based systems; however, it seems to be a bit behind Communique! in compatibility.

Package	ISDN	Switched 56	TCP/IP	Analog	SUN/UNIX	PC/Windows	Macintosh	Multipoint	Whiteboard	File Xfer	App Share	H.320	Pricing
ShowMe			■		■			■	■		■		$3270 single user $8430 three users
Communique!	■	■	■		■			■	■	■	■		$2495 single user $595 for SHARE
PSVC			■		■			■					$995 single user $29,850 50 node network
BeingThere Pro							■	■		■			$599 single user $499/user (10 or more)
Cameo	■	■		■			■		■	■			$1499 LAN or analog, $2500 for ISDN or SW 56
ShareView 3000				■			■		■		■		$3999 single user
Connect 918	■						■	■	■	■		■	$5899 ISDN, $4299 LAN
Visit Video	■	■		■		■			■	■			Approx. $5000 for both MAC and PC versions
AT&T Telemedia Pers. Video Sys.	■	■				■		■	■	■	■	■	$5995 with 486 PC app. $92,500 8 port MCU
PictureTel LIVE	■	■				■		■	■	■	■	■	$5995 single user, $92,500 8-port MCU
VideoConferencing for Windows			■			■			■	■			$995 software only
VTEL 115	■	■				■		■					$14,950 VTEL 115 $90,000 8-port MCU-II
Talkshow		■		■		■	■		■				$199 software only 1 user approx. $2700 whole pkg.

Table B-1
Comparison of Videoconferencing Products

ShareView 3000 seems to be one of the more promising products for Macintosh because it offers full video and audio, a shared whiteboard, and true application-sharing. A Windows version will be released shortly that is compatible except for the application-sharing. Two drawbacks of ShareView 3000 are the lack of multipoint conferencing and H.320 compatibility; however, both will be supported in the future.

Connect 918 also seems to be a viable candidate. It operates over ISDN or LAN lines and provides H.320 compatibility. It will soon allow for videoconferencing between Windows and Macintosh platforms. Unfortunately, application-sharing is not supported and a videoconference is limited to three parties.

For Windows machines, the AT&T Telemedia Personal Video System is an extremely strong candidate. It provides all the necessary functionality such as application-sharing, interactive whiteboard, file transferring, and H.320 compatibility. PictureTel's LIVE also seems to be a good choice. It is fully compliant with H.320, making it one of the more compatible systems available. LIVE provides full video, audio, a shared whiteboard, and application- sharing. The VTEL 115 will soon support application-sharing, but VTEL will only sell the entire system, including the computer, as one unit. The VTEL 115 is also not fully H.320-compliant. Of all the systems examined, InVision's VideoConferencing for Windows is the only one that supports TCP/IP connections.

Color video, audio, and the capability to run across different networks and phone lines seem to be pretty standard among most of the products examined. Multipoint conferencing, application-sharing and cross-compatibility seem to be causing the most problems. Most products that do not currently offer these capabilities will offer them in the future. However, the products that offer the major capabilities today have a big advantage over the ones that will in the future. By the time some companies are announcing the new capabilities, the other ones will have already worked out most of the bugs.

Technology has just not advanced to the point where fully functional, cross-compatible systems are available. However, the desktop videoconferencing industry is very competitive, which will force vendors to provide the highest quality products with the most functionality. It will not be long before the perfect systems are on the market. Until then, customers must decide which of the different capabilities are the most important and select the product which best provides the desired functionality.

APPENDIX C

SATELLITE COMMUNICATIONS

MAFIS requires a data communication methodology that provides global coverage, even in remote areas where telephone lines do not exist. Therefore, satellite communications are necessary. There are many different satellite systems, but the one that is best suited for MAFIS is called the International Maritime Satellite (INMARSAT).

The INMARSAT network began as a ship-to-shore communications system. It has now grown to be one of the largest commercial and military satellite communication systems in use. Figure C-1 shows how an INMARSAT connection is established between a remote site and a central location. The remote site uses a portable terminal to communicate with a satellite. The satellite then connects with one of several ground stations around the world, usually the one closest to the central location. A landline, such as a telephone line, is then used to connect the ground station with the central location. If security is needed, an encryption device such as an STU-III can be used at each end before any data is transmitted.

There are four types of INMARSAT connections. INMARSAT-A is the one generally used. It offers high-quality voice and high-speed fax/data transmissions. The cost for a terminal is \$30,000 to \$40,000, and the service cost is \$7 to \$10 per minute. INMARSAT-C is cheaper (\$8,000 to \$15,000 for a terminal), but it can only send data or messages. There are no voice capabilities, and transmission speeds are low. INMARSAT-M offers voice transmission, but the quality is lower than INMARSAT-A. An INMARSAT-M terminal costs \$15,000 to \$25,000, and service costs run \$4.00 to \$5.50 per minute.

INMARSAT-B is a direct successor of INMARSAT-A and is the method most applicable to the MAFIS system. Transmission speeds up to 64 kbit/sec are available, and services at 256 and 384 kbit/sec will be available in the future. The 64 kbit/sec capability provides for up to 11 digital voice channels or 20 data channels over a single terminal. It is possible to conduct videoconferences over this connection, and normal video data can be transmitted at 30 frames per second. Group 4 faxes can be sent at three seconds per page.

INMARSAT-B is cheaper than INMARSAT-A. The cost of a terminal is \$35,000, and service costs run \$4 to \$7 per minute. An INMARSAT-B terminal averages 100 kilograms, and the size of the antenna (diameter and height) is approximately 0.9 meters (Brunstrom, 1993).

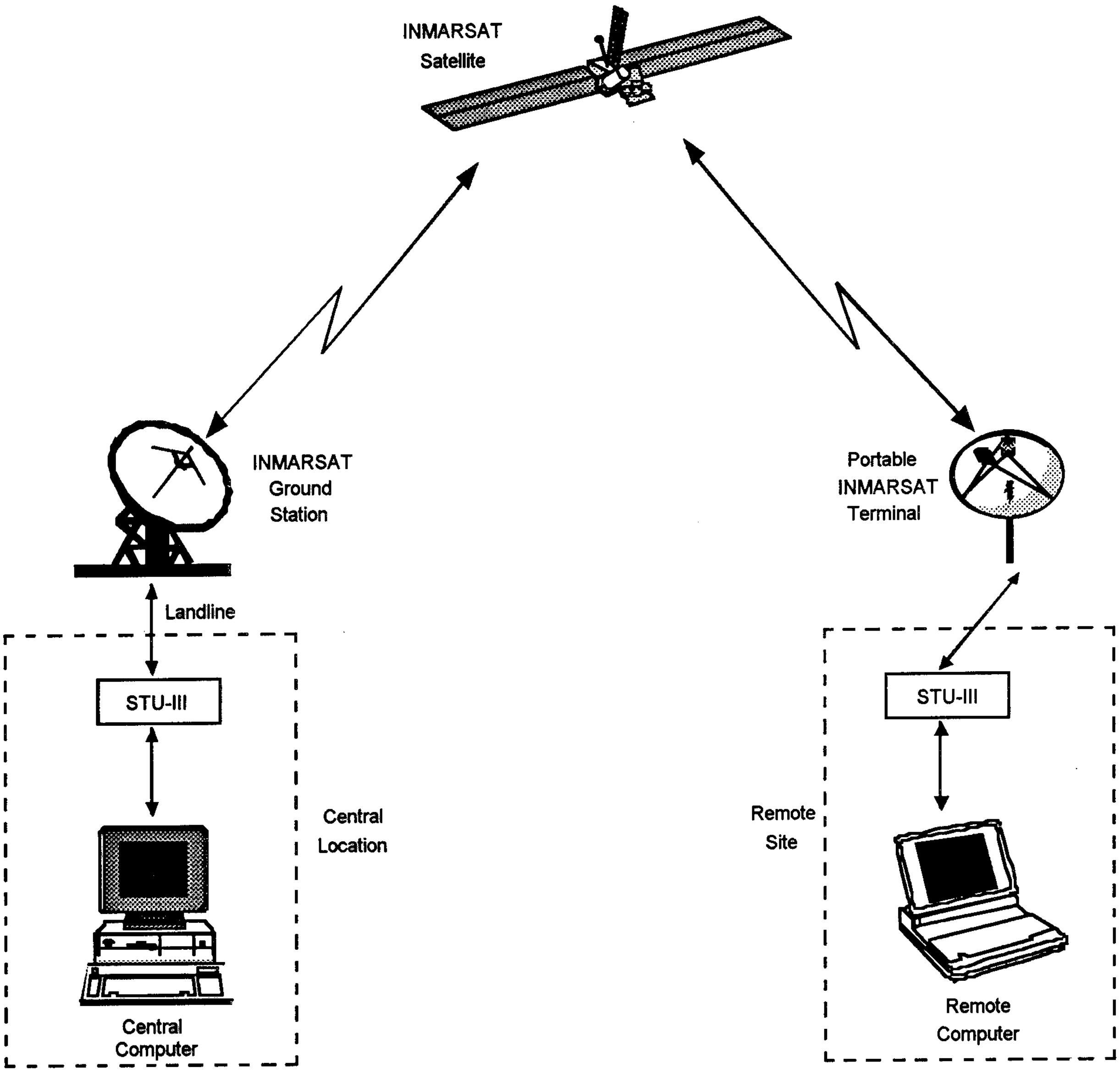

Figure C-1
Sample International Marine Satellite (INMARSAT) connection

APPENDIX D

SPORTS AND IMAGEHAWK

The Second-generation Portable Remote Telecommunications System (SPORTS) is a PC-based system that allows users to acquire, process, and transmit textual and graphical information to other computer systems. The system utilizes commercial off-the-shelf hardware, and there are versions for both DOS and Windows. SPORTS operates on any 386 or higher computer, including both desktops and portables. SPORTS is certified as being compliant with the National Imagery Transmission Format (NITF) 1.1 standard.

The user interface was designed for ease-of-use in high-stress environments. SPORTS supported Operations Desert Shield and Desert Storm, and is used daily by Special Forces.

SPORTS offers a large set of image processing capabilities. It can capture and display 8-bit grayscale and 16/24-bit color images from a video source such as a video camera, digital camera, still video player, VCR, or scanner. The images can be cropped and compressed, and subsets of images can be stored on the system. Users can zoom, enhance, and annotate images. The system can even measure the two-dimensional lengths of objects in an image.

SPORTS also includes an integrated word processing package which allows users to create and edit text files.

The system can receive and transmit a queue of different file types (compressed images, word processing documents, facsimile messages) over several military and commercial circuits:

- UHF SATCOM, INMARSAT, TRITAC/TACSAT satellites;
- KY-57, KY-68, KG-84A/C, Sunburst cryptos;
- Kodak Berkeley Research 86SC Forward Error Correction (FEC) device;
- STU-III secure telephone;
- Cellular phone/modem; and
- Wireline, PBX (e.g., SL-100), public switched telephone network.

SPORTS also has the capability to capture and transmit video over a 9600-baud secure phone line. Current performance is limited to 5 frames per second (FPS), but the system will be improved to accommodate 15 FPS.

The ImageHawk system is a portable data collection and transmission system. The system includes a 486SX/25 MHz Notebook PC, digital still camera, cellular modem, and an auxiliary power supply. All components fit into a specially designed briefcase for ease of transportation. The system operates under Microsoft Windows.

The system was designed to allow for the easy transmission of data between a home base and a remote site. Documents and graphics can be scanned at the home base and transmitted to a field crew. The remote site can use the digital camera to capture images and send them to either the home base or another remote site. Likewise, a remote site can create and transmit text documents. The software will also enhance images to reveal obscured details.

There are several options available for the ImageHawk. The user can include a video camcorder and frame grabber, scanner, video printer, and an integrated cellular phone/modem. For added communication ability, a radio hookup or a portable satellite terminal hookup is available. An image enhancement algorithm is available for underwater applications. The ability to view up-to-the-minute weather patterns and forecasts at a remote site is possible through an add-on product called WEATHER for Windows.

In the future, the ImageHawk system will be able to record, transmit, and play back video and audio clips. Also, an integrated positioning/mapping capability will be added.

APPENDIX E

CASE-BASED REASONING

This appendix provides an explanation of the CBR technology. Also included are a comparison of CBR and other AI techniques, and several examples of how CBR has been used in real-world applications.

CBR Explained

CBR is an AI technique that catalogs previous experience into separate cases. When presented with a problem, the CBR system searches the database for cases that are similar. If a case is found with exactly the same characteristics as the new problem, the solution should also be the same. However, this rarely happens. Instead, the system presents several cases that match the new problem as closely as possible. Given the solutions of the other cases, the user will develop a solution to the new problem. The new problem and its solution are then added to the database as a new case. The above process is actually a series of five steps: representation, indexing, storage and retrieval, adaptation, and learning/generalization (Barletta, 1991).

Representation

The first step in developing a CBR system is to determine how a case is to be represented. This initial design phase is generally a coordinated effort between users, managers and system developers. The structure of the database, including a list of attributes used to describe each case, is developed. Standards are also determined that specify which words will be used to describe problem features, which features will be used to index cases, and how new cases will be authored.

The simplest case will be a list of attributes that lead to a specific outcome. However, a CBR system with this design will not be very powerful. A better method is to represent a case as a connected set of subcases that model the situation. For example, instead of modeling a car as only a list of characteristics, it can be modeled with a small list of characteristics and a collection of subcases that each model a specific part such as the braking system, chassis, suspension, electrical system, and so forth. This approach provides an object-oriented structure to the database design and adds a great deal more power to the CBR system.

Indexing

The second step, case indexing, provides a way to rapidly determine when a stored case is considered relevant to the current problem. There are four methods used to index cases: nearest neighbor, inductive, knowledge-guided, and a combination of the three.

The nearest neighbor approach is the easiest to implement. It indexes cases based on a weighted sum of features in the input problem that match stored cases. In its simplest form, each attribute is weighted equally; thus, a case that matched the input problem on seven attributes is

preferred over a case that matches on six. However, some attributes may be more important than others. This is implemented by giving stronger weights to the more important attributes. For example, consider a $6,000 1982 station wagon. If a car's body style is more important than price or age, then a $13,000 1992 station wagon will match more closely than a $6,000 1982 sedan. The nearest neighbor approach works well when the retrieval goal is not well-defined or there are only a few cases in the database. The biggest drawback of the nearest neighbor approach is that it is almost impossible to determine a single set of weights that will determine the best matching cases for every input problem. The importance of certain attributes may be heavily dependent on the values of other attributes. This would mean that almost every input case should have its own set of attribute weights.

An inductive indexing approach is very useful when there are a very large number of cases in the database. The system examines each case to determine which attributes best discriminate between different outcomes. The cases are then arranged with respect to these induced features, thereby structuring the database so that the time necessary to find matching cases is minimized. This approach works best when the case outcomes are well-defined and there are a large number of cases. The major drawback of this approach is that it may take a substantial amount of time to perform the induction and database structuring. Fortunately, this only needs to be done at the beginning and at certain intervals as cases are added to the database.

The knowledge-guided approach uses existing knowledge about each case to determine which features are important for retrieving the case. This is similar to applying an expert system because the knowledge is incorporated into the database in the form of a rule-based domain model. This approach works well when there is enough information about each case to sufficiently explain the outcome. However, as the range of attributes increases, it becomes more difficult to establish a set of rules to perform the indexing. The knowledge-guided approach is generally applied in combination with other indexing techniques to overcome this disadvantage. It is still beneficial because there is almost always some useful indexing information in some cases, just not all of them.

Storage and Retrieval

The main goal of case retrieval is to return the most similar past case or cases that are relevant to the input problem. The manner in which cases are stored in the database can greatly affect the efficiency with which the cases are retrieved. Most case-memory structures fall between two different methods, associative and hierarchical. In associative retrieval, each feature of a case is indexed independently of all other features. This approach is useful when a single database is being used for several retrieval tasks. The hierarchical approach entails organizing case features into a general-to-specific, tree-like concept structure. When the retrieval task is well-defined, the hierarchical approach is best because retrieval time is much less than that of associative methods.

Adaptation

The goal of case adaptation is to take the best retrieved case and transform it to meet all of the input situation's needs. Many CBR systems incorporate adaptation rules to automatically adapt stored cases for specific problem domains. Pieces of existing cases can also be used to adapt the retrieved case. This approach is useful when it is difficult to develop enough rules to perform the adaptation. In many cases, complete adaptation cannot be accomplished. It is then up to the user to provide the rest of the necessary information.

Learning/Generalization

Each adapted case is added to the database to be used in future comparisons. Therefore, the longer a CBR system is used, the greater the likelihood that an exact match of an input problem will be found. The need for adaptation then diminishes. Also, as the database becomes large, generalization can be used to develop prototype cases that meet the feature requirements for specific case classes. These prototypical cases are added to the database along with the real cases and are accessed in the same manner. This allows the CBR system to recognize and exploit hypothetical situations that can be used to improve the system's accuracy in the long run.

Comparisons Between Case-Based Reasoning (CBR) and Other Artificial Intelligence Techniques

Statistical pattern recognition has been successfully used for many years to analyze and classify data. However, the basis behind this technique is the use of mathematical equations. This method is therefore limited to processing numerical data only. Another limitation is that the equations themselves provide the only explanation of the analysis results.

Neural networks are very adept at analyzing large amounts of data. They are designed to handle situations never before encountered, providing that they are trained correctly. They are also very good at analyzing data that is incomplete or contains errors. However, neural networks suffer from the same disadvantages as statistical pattern recognition methods. They are mathematical in nature, so only numerical data can be processed. Also, the weights between a neural network's nodes provide the only explanation for results. These weights are just a collection of numbers, so the information that can be gathered from them is severely limited. Lastly, the performance of a neural network is heavily dependent on how it is designed, namely how many layers the network has and how many nodes are in each layer. The best way to design a neural network still remains unclear.

Rule-based expert systems are very powerful at solving problems with clear-cut solutions. The main bottleneck in developing expert systems is the generation of the rule base. Expert systems are also very difficult to maintain. As new data is made available, new rules must be added. This is not a simple task because the new rules must be meticulously integrated into the existing rule base. Also, great care must be taken to ensure that rules do not contradict one another. Like the previous two techniques, expert systems lack the ability to sufficiently explain

their results. All an expert system can do is list the chain of rules followed to achieve a given result. In simple cases, this is probably enough. However, the real explanation may get lost in a substantially long list of rules.

The case-based methodology offers several advantages that are not present in other AI techniques. First, the results obtained from a CBR system can easily be explained. A set of rules generated by the indexing process can be used, but they are only as useful as the rules reported by an expert system. The example cases retrieved by the CBR system provide more important information about the analysis results. If an obvious result cannot be determined, the user can examine the example cases to assist in determining a solution.

Another advantage of CBR systems is that they do not exclusively rely on numerical data. Other types of information (including images, sound, free-form text and others) can be included in a case. It may not be possible for the CBR system to use this type of information to obtain results. However, this type of information may be invaluable to the user when a comparison between past cases and the current problem must be made manually.

When pieces of data are missing from the input set, other techniques may produce unreliable results. When a CBR faces incomplete data, it simply generates a larger number of possible solution cases. The user can then determine if supplying additional data will narrow the list.

One of the biggest advantages of CBR systems is the ease of maintenance and expansion. As mentioned above, adding rules to an expert system can be a very difficult process. Adding information to a pattern-recognition system may involve modifying the underlying equations. Neural networks need to be retrained if added information is to be incorporated into them. Adding information to a CBR system only requires that the new case be added to the database, and possibly that the database be reindexed (Buta, 1994). As mentioned before, reindexing may only be necessary at certain times.

In short, a CBR system can present all cases relevant to a given situation, clearly explain why those cases are relevant, and indicate how the previous cases may be applied.

Real-World Case-Based Reasoning (CBR) Applications

There have been several applications of CBR technology in areas of business and manufacturing. This section describes some of these systems and the benefits they have provided. Also in this section are brief descriptions of some commercially available CBR tools.

Large banks receive up to 2,000 telexes every day describing different kinds of transactions. The classification and routing of these telexes used to be done by hand. Cognitive Systems was contracted to automate this process. Cognitive took one year to develop an expert system called Prism to accomplish this task. Cognitive then built a second system for another

bank, this one taking only four months. The new Prism took between two and seven seconds to process a telex and it achieved an accuracy rate of 72 percent.

Cognitive then decided to build a CBR version of the second system as an experiment. It was developed in two weeks, processed telexes in 0.19 to 0.25 seconds, and achieved an accuracy rate of 77 percent. The customer had the expert system replaced with the new case-based version (Barletta, 1991).

Another example pertains to manufacturing. Lockheed uses composite materials such as Graphite-Epoxy to produce components for airplanes, satellites, and missiles. These parts must be cured in an autoclave for four to eight hours. Since the time is so long, Lockheed places several parts in the autoclave at one time. Different parts have different sizes, shapes, and composition; thus, they require different heating characteristics. The air currents in the autoclave produce hot and cool spots, also affecting the curing process. Therefore, Lockheed spends much time determining how different parts should be positioned in the autoclave. The placement of the parts is based more on experience than knowledge because the placement process is not well understood. Rules could not be easily developed for this process, so Lockheed decided to develop a CBR system to determine the placements. The system, called Clavier, greatly improved the process. As of August 1991, Clavier was still in use at Lockheed's Sunnyvale Plant (Barletta, 1991).

CBR techniques are also popular in customer service applications. The SMART system, developed by Compaq Computer, is an integrated call-tracking system that can diagnose problems experienced with Compaq products. Before the system was used, approximately 50 percent of all problems were resolved on the first call. By using SMART, that result increased to 87 percent. Compaq estimates that SMART paid for itself within a year (Allen, 1994).

A CBR system was also designed to rate corporate bonds using the Standard & Poor's (S&P) bond rating scheme. Two sets of data were generated for testing purposes with one of the sets being incomplete. The data in both of these sets had never been seen by the CBR system. After running the data through the system, the results matched the S&P recommended ratings 90.4 percent of the time for the complete data set and 84.4 percent of the time for the incomplete data set (Buta, 1994).

There are a few CBR systems available commercially. One of these systems is called CBR Express and is produced by Inference Corporation. CBR Express runs under Microsoft Windows or MVS.

CBR Express is a case-based reasoning shell for developing experience-based knowledge systems. It provides three major capabilities: case-based reasoning, natural language text retrieval, and an interactive user interface. Users can build knowledge bases using a case history approach and free text input. Fill-in-the-blank forms are used to facilitate data entry. For information access, screens are presented for describing problems, answering questions to narrow each inquiry, listing possible solutions to resolve every case, and starting each new problem

through an initial search. When cases are authored for inclusion into the knowledge base, screens are presented for entering and defining cases, creating appropriate questions/answers for each case, and defining effective solutions.

APPENDIX F

ANALYSIS OF ISAAC CAPABILITIES

The Integrated Simulation Assessment of Airbase Capability (ISAAC) model was to be the main component of the Enhanced Simulation Assessment of Airbase Capability (ESCAM) system. As a result of drastic funding reductions, ISAAC is the only component of ESCAM system that is anywhere near being mature. ISAAC is a decision support tool that analyzes the competing demand for 12 airbase resources required to launch and maintain combat sorties of a single unit (e.g., a Tactical Fighter Wing). ISAAC is implemented using a Monte Carlo discrete event simulation technique. To perform an assessment of a specific unit, ISAAC requires the following input data: Operational Flight Tasking, Airbase Resources, and Maintenance Task Networks (MTNs). This data is defined in a collection of many different files, each which contain column-sensitive data. A User Interface Prototype (UIP) was developed to enable the user of the system to easily manipulate the data used in ISAAC, but to this point has only limited capability. The current capabilities of ISAAC include: assess the sortie generation capability of a combat unit, identify operational and logistics limiting factors, experiment with alternate logistic and operational plans, determine required resources, predict supportable levels of effort, and evaluate Status of Resources and Training (SORTS) data. Currently, there is only MTN data available for the F15 and F16 aircraft.

ISAAC and the UIP model were designed to run on any 80x86 processor workstation. The documentation called for a minimum of 4 megabytes (MB) of extended memory which had to be configured as a virtual disk. We obtained the software and installed it on a 80486 machine with 8 MB of extended memory running MS DOS 5.1. According to the documentation, VDISK.SYS and RAMDRIVE.SYS were suggested as the utilities to create the ram disk, with VDISK.SYS being the most compatible with the software. We were unable to obtain the VDISK.SYS utility so we implemented the ram disk using RAMDRIVE.SYS. We were successful in getting the UIP program to bring up the initial logo screen and the main menu, but we were unable to run any other component of the UIP. This could be a result of not having VDISK.SYS.

The Logistics Composite Model (LCOM) shares many similarities with ISAAC. LCOM is designed to simulate a broad range of aircraft operations, maintenance functions, supply functions, and scheduling at an Air Force base. The LCOM model reads a LCOM database, which is a collection of 11 different column-sensitive forms. These forms include: Resource Definitions, Attribute Definitions, Task Definitions, Task Network Definitions, Clock Decrements, Empirical Distributions, Shift Change Policies, Mission/Activity Definitions, Aircraft Assignment Search Patterns, and Sortie Generation Data. We obtained the F16 database; this file contained over 10000 lines of forms and had very little documentation. The process of developing these forms is partially automated but there still is a good deal of work that must be done manually. Programs exist to prepare and format Maintenance Data Collection (MDC) system information into LCOM forms for unscheduled maintenance tasks only.

The majority of the LCOM forms are contained in the Task Network Definitions. The Task Definitions include such information as the priority and duration of the task and the resources required by it. A delay time can also be defined in the Task Definitions. The Task Network Definitions define the sequence of performing maintenance tasks. There is great flexibility in writing Task Networks but the logic is somewhat cryptic and hard to follow.

HQ AFMEA is pursuing development of a Modern Maintenance Modeling Tool. This program has identified needs of the LCOM community to develop a new system with object-oriented modeling capabilities, modern graphical user interfaces, and integrated data importation and analysis modules. This tool will use the Integrated Model Development Environment (IMDE), which is a domain-independent Computer-Aided Software Engineering (CASE) tool for the development of object-oriented discrete event simulations. IMDE is domain independent because users decide what the objects they build will represent. This is in contrast to ISAAC and LCOM which are heavily tied to the airbase logistics domain. IMDE is integrated with an object-oriented database which is used to store the user-created objects as well as many other components of the model.

Models are constructed in IMDE by first constructing the parts of the model which represent entities in a given model. These parts are then hooked together to form a complete simulation. The completed simulation can then be run and the results can be analyzed in the post processor. Once a project has been constructed in IMDE, it is easy to alter the parameters of the model and run the new project. Within IMDE, there is a concept of user level which facilitates the use of a diverse group of people to work on a project.

Both LCOM and ISAAC use column-sensitive ASCII files to define and drive the model. A good working knowledge of either system is necessary to look at these files and deduce pertinent information. Within the IMDE environment, users have a graphical picture of the objects they create. Someone not familiar with IMDE could look at a graphical representation of the objects in the model and should be able to understand to some degree what is being modeled. IMDE also allows the user to document individual objects and store this documentation in the database which facilitates the maintenance of the models.

Although, we have never developed simulations in either ISAAC or LCOM, we believe that the process would be very time consuming. We also believe that training people to use either ISAAC or LCOM would be much more difficult than training someone to use IMDE.

U. S. Government Printing Office 1995 650-075/00058